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THE MANAGEMENT OF PENETRATING WOUNDS AND SUPPURATIVE ARTHRITIS OF THE KNEE JOINT IN THE MEDITERRANEAN THEATER OF OPERATIONS

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The purpose of this report is to present experiences in the Mediterranean Theater of Operations with penetrating wounds and superimposed suppurative arthritis of the knee joint, and to outline a regimen of management which proved highly effective for these conditions.

Penetrating wounds of the knee joint are serious wounds[20]. The damage done when the wound was received is immediately prejudicial to subsequent function of the joint, and, of greater importance, each wound is potentially a site of suppurative arthritis. Once established, suppurative arthritis endangers the limb, and even the life of the patient. Evidence of this is shown in the data supplied by Frankau in the British "History of the Great War" (World War I). In the early stages of that conflict, the death rate from wounds of the knee joint was very high; amputations were performed in 60 per cent. of the cases uncomplicated by injury to the bone, and at least 80 per cent. of the patients with injury to the bone suffered the loss of the extremity. With improved methods of management, the amputation rate fell to 25 per cent. in 1916 and to only 7 per cent. in 1917, while the death rate declined to 8 per cent. Buxton, reporting 273 wounds of the knee joint treated in a Base Hospital during two Libyan campaigns in World War II, cites incidences of 34.8 per cent. suppurative arthritis, 4.4 per cent. amputation, and 1.8 per cent. mortality. These data established the fact that wounds of the knee joint are among the most serious injuries a soldier may receive.

Prior to the invasion of North Africa, several authorities[7,17,24,33] had recommended similar plans of management for wounds of the knee joint which were seen early; these plans consisted of the surgical removal of foreign bodies, foreign material, and loose chips of bone and cartilage, thorough lavage, and closure of the synovial membrane or capsule, followed by immobilization. A thorough sprinkling of one of the sulfonamides into the joint also had been suggested[24].

The value and necessity of closing the joint in the surgical treatment of these wounds have been stressed repeatedly. Pool attributed the poor results in wounds of the knee joint in the early part of World War I, in part, to "an undervaluation, on the part of surgeons, of the resistance to infection which the synovial membrane of a joint offers". Other writers[5,8,10,22] have emphasized the apparent bactericidal or bacteriostatic property of the synovial fluid. With the joint closed, this property was considered more effective, the

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hazard of secondary intra-articular infection was obviated, the articular cartilage was not left exposed, and a greater return of function could be expected.

For wounds seen late or after sepsis had become established, these authorities recommended that closure of the synovial membrane be omitted, because closure was in direct conflict with the accepted principles of drainage for infected knee joints. This modification of the regimen for cases seen late was recommended, despite the observations of Pool in World War I and of others[16,23,25,30,35] in the early phases of World War II that, after the joint cavity had been cleaned thoroughly, closure of the synovial membrane was permissible and was indicated for as long as twenty-four hours after the wound had been received.

Although adequate drainage has remained a fundamental principle of the treatment of suppurative arthritis of the knee joint[1,3,12,19,26] since World War I, the highly heralded Willems treatment[9,36], consisting of forced active motion combined with drainage, which was advocated during that War, has not maintained favor[28] and has been generally discarded, in spite of the fact that Steele stressed its advantages in 1929. In World War I, Abbott utilized a posteromedial incision for drainage of the knee joint; since then, Henderson, Babcock, and Orr have recommended posterior incisions for this purpose. Parapatellar incisions, however, have been employed most generally[3,9,12,14,17,19,25,26]. Immobilization in a Thomas splint or in plaster, after drainage had been established, has been customary. The same authorities, who recommended the plan of management for penetrating wounds of the knee joint which has been outlined here, also recommended drainage for superimposed sepsis which had become established in the joint. During and since World War I, the value of combining irrigations of chemical solutions with drainage has been stressed[5,6].

In contrast to open drainage, some authors[6,31] recommended aspiration of the joint fluid in cases of blood-borne suppurative arthritis; for this condition, Jones recommended a small arthrotomy incision, thorough lavage, and then closure of the joint. These procedures, however, were not recommended for suppurative arthritis complicating intra-articular wounds.

The reported results in cases of suppurative arthritis of the knee joint, following wounds caused by missiles, were far from encouraging in World War I [11,16] and in the early part of World War II [2,23,25,32]. In spite of what appeared to be adequate drainage, in many cases the ravages of sepsis led to amputation of the limb or to death. Even if these misfortunes were avoided, many joints became totally destroyed by the septic process and fusion resulted. Ogilvie, although recommending drainage for patients with suppurative arthritis, stated that the battle against sepsis was usually decided within four days; if the septic process was not controlled in that time, amputation was usually necessary to save life.

The French, in the last part of World War I and in the early phases of this War[30], had accepted the belief that, once suppurative arthritis had become established, the joint was doomed and the patient's life was endangered. Fear of such dire consequences led them to adopt primary resection as a prophylactic measure in the patient with a severely damaged joint—recognized as especially vulnerable to sepsis—and secondary resection as a therapeutic measure for acute suppurative arthritis, if the infection failed to respond quickly to long anterolateral incisions and thorough immobilization. Pool recommended resection for suppurative arthritis which was superimposed on a severely damaged joint. French, Russian[21], and German[16,23,32] surgeons practised resection extensively throughout World War II, rather than risk the hazards of suppuration of the knee joint.

Early in the experience in North Africa, it was seen that penetrating wounds of the knee joint could be classified roughly, according to the severity of damage to the intra-articular bone and cartilage, into three groups:

Group A: Wounds in which there had been no damage to the bone or cartilage;

Group B: Wounds involving minimum or moderate damage to portions of the condyles of the femur or tibia;

Group C: Wounds involving severe destruction of the joint components.

While the results varied somewhat in 1943 during the Tunisian, Sicilian, and early Italian Campaigns, according to the degree of intra-articular damage, it appeared that the surgical management of the case also had a direct effect. The recommended plan of arthrotomy, intra-articular débridement, lavage, closure of the synovial membrane, and immobilization in a toe-to-groin plaster cast was usually followed in the forward hospitals for wounds of the knee in Groups A and B. If, however, the surgical treatment was delayed for more than eight to twelve hours after the wound had been received, or if there was sepsis of the joint, closure of the synovial membrane was omitted in order to permit drainage. In the cases in Group C, the wounds were often extended and were always left open for drainage, but extensive intra-articular débridement was not performed.

Suppurative arthritis in Group A (those cases without bone or cartilage damage) was seldom, if ever, observed; and it was rare in Group B (the cases with minimum or moderate damage within the joints). In these favorable cases, however, it was noted that, if closure of the synovial membrane had been omitted, healing was often slow and the subsequent joint function was frequently limited beyond that to be expected from the wound damage. In other cases of Group B, there was lingering sepsis and slow destruction of the joint. Although in these cases the joints were the sites of suppurative arthritis, the open drainage sufficed to prevent systemic sepsis and toxaemia. Obviously, the joint was doomed. Unfortunately, no data on the incidence of this complication are available, but the observation was general, and confirming reports reached the Theater from the Zone of the Interior. In Group C, which included the joints with severe destruction, septic arthritis was the rule. In each of these patients, the joint had been destroyed when the wound was received, and an ankylosed knee was the best that could be expected. Although it was recognized that the joint was destroyed and that suppuration was likely, resection, as practised by the French in this type of injury, was not considered. Fortunately, no deaths were reported, and only a few amputations were necessary.

During the Cassino-Anzio impasse, in the several Base Hospitals in Naples, a sharp rise was noted in the incidence of suppurative arthritis. This rise was coincident with a wave of surgical conservatism among the forward surgeons at the Anzio Beachhead, accounted for, at least in part, by the conditions under which they were working, and resulting in a minimum of exposure and intra-articular débridement. The increased incidence of suppurative arthritis focused attention upon the problem of wounds of the knee joint and their complications, and permitted the following study:

MATERIAL

Nineteen patients having wounds of the knee joint, with potential, early, or late sepsis within the joints, were studied closely; and data on them were compiled, in conjunction with the formative stage of a program for the adjuvant use of penicillin in the management of the wounded. Approximately thirty-five other patients were also observed and studied, but no data were gathered. Both groups of patients had been wounded; they had received initial surgical treatment in the forward hospitals a few days or a few weeks before, and had been transferred to Base Hospitals.

No sepsis of the knee joints was observed during this study in those patients treated by complete initial surgery, closure of the synovial membrane or capsule of the joint, and adequate immobilization[34]. Of course, this was a highly significant observation. Definite suppurative arthritis of all degrees of severity, with prolonged drainage and slow destruction of the articular surfaces, was observed in several patients whose joints had moderate or even minimum intra-articular damage, but where the excisional surgery had been poor and the joints had been left open for drainage. Compound, comminuted fractures of the patella were noted as the source of sepsis in several cases.

A particularly pertinent observation—made in several other cases of severe sepsis (not included in the nineteen observed closely) by the Surgical Staff of the Ninth Evacua-

tion Hospital [34], and confirmed in this study in approximately fifteen patients with sepsis of the knee joint of varying severity—was that each had unexcised, traumatized, devitalized, articular cartilage. Therefore, thorough and complete initial intra-articular surgery had not been performed.

An aggressive surgical regimen was instituted in each of the nineteen patients under close observation; antibacterial agents and whole-blood replacement were used as adjuvants. Penicillin, in doses of 25,000 units intramuscularly every three hours, was employed until the danger of continuing sepsis was past, and usually until all the wounds had healed. The local instillation of 1,000 units per cubic centimeter was supplemental. Blood transfusions were given in amounts which maintained a hematocrit level of at least 40 per cent. of red cells. Each joint was immobilized after surgical treatment by a single hip spica or by a Tobruk splint, until it was certain that all danger of a flare-up of sepsis was past and that the wounds were healing. Then the joints were mobilized.

Eight knee joints with evidence of intra-articular trauma, in which there had been only minimum exposure at the time of the initial operation, were reopened to be sure that the excisional surgery had been adequate, even though no definite signs of infection were present. In four cases, potential foci of sepsis, in the form of unexcised, devitalized areas of articular cartilage, were found and were removed. After thorough irrigation, the joints were closed, penicillin was instilled into the joint cavity, and immobilization was provided. No suppurative arthritis followed and function of the joints, limited only by the trauma associated with the wound, was obtained (Case 1).

Six knee joints with definitely established suppurative arthritis, but without septic destruction of the joint, were opened widely. The joint was cleaned of all devitalized tissue, debris, and foreign material; blood clot and pus were removed by thorough irrigation. The synovial membrane was sutured. Penicillin was instilled and immobilization was provided. Aspiration, irrigation, and reinstillation of penicillin were performed at intervals of twenty-four or forty-eight hours for about a week. Very little fluid reaccumulated, however, and the attempts at aspiration were usually unsuccessful. The sepsis was controlled, and function of the joint, limited only by the damage caused by the missile which produced the wound, resulted in every case (Cases 2 and 3).

Subacute septic processes of several weeks' duration in two other knee joints—one associated with a comminuted fracture of the patella and the other with a septic fracture of the lower third of the femur, which dripped pus into the joint—also were treated surgically. At arthrotomy, the necrotic areas of articular cartilage (produced in each case by the septic process and not by the missile) were removed with the curette, and the edges were trimmed of loose tags. The comminuted patella in the first case was completely excised. Both menisci in each knee were devitalized and friable; they, too, were removed. After thorough cleansing of the joint by irrigation, the synovial membrane was closed and the usual regimen was instituted. In both cases the sepsis was controlled, and delayed skin suture produced prompt wound healing. In each case, a fractured femur, associated with sepsis, handicapped a program for knee motion. However, from 10 to 20 degrees of motion was present in each knee joint when the patients were transferred to the Zone of the Interior (and also at a later check-up) (Case 4).

Limb-endangering sepsis in three knee joints was eradicated by resection of the joint. In one, associated with a contralateral amputation in the upper third of the thigh, the sepsis was so severe as to endanger the patient's life (Case 5). This condition had resulted from infection of a relatively innocent-appearing, but poorly debrided, compound fracture of the medial tibial condyle, with a line of fracture extending into the joint. In these three knee joints, treated by excision of the infected necrotic bone and cartilage, by resection, and by staged procedures directed at wound healing, sepsis was controlled, the wounds healed, and bony fusion was progressing at the time the patients left the Theater (Cases 5 and 6).

In six French Colonial soldiers, whose knee joints were the sites of severe suppurative arthritis, resection of the joints was performed during the same period by surgeons at the Ninth Evacuation Hospital[4] (which served as a Base Hospital for the French in the Naples Medical Center). The arthritis had developed after relatively minor damage of a typical penetrating wound, and, as stated previously, all of these patients received incomplete initial surgery. The sepsis in each knee joint definitely endangered the patient's limb. An amputation had been performed previously for comparable sepsis in a seventh case. In this group of patients, the wounds had healed and the knee joints were fused prior to transfer to the French hospitals in North Africa.

Consideration of the previous experience and of the observations made in these cases, which were studied carefully, led to the standardization of a plan for the management of all knee-joint wounds—penetrating or perforating, due to shell fragments or bullets—in the forward and base areas, regardless of the time which had elapsed since the wound was received. The objectives of this plan were the prevention of sepsis, the elimination of early established sepsis, and the optimum preservation of joint function.

A. *Forward Area*

Following adequate preparation by transfusions of blood or plasma and by appropriate roentgenographic studies, the patient was removed from the litter and placed on an operating table which permitted automatic angulation opposite the knee in order to facilitate intra-articular exposure. The skin preparation and draping were circumferential. A tourniquet often was applied to secure a dry operative field. The joint was opened to the extent and in the location which provided the best access to the intra-articular damage. A separate, standard arthrotomy incision was frequently necessary. Good light, assistance, and retraction were essential. Foreign bodies and other material were removed. Loose bone chips, areas of loose or devitalized cartilage, and damaged menisci were excised. The removal of devitalized, fragmented articular cartilage was considered exceedingly important. Defects in the condyles were trimmed evenly. A comminuted patella usually was excised. Thorough irrigation of the joint cavity completed the excisional surgery. The synovial membrane and, at times, the capsule were sutured; and from 10,000 to 20,000 units of penicillin was instilled into the joint cavity. Indirect injuries produced by fractures extending into the joint were managed similarly to ensure that no debris, loose fragments, or large blood clots remained. When loss of soft tissue precluded closure of the synovial membrane or capsule, it was desirable to rotate flaps of fascia or skin in order to achieve the desired closure (Case 7). An open joint was accepted only when the extent of the damage made it certain that the return of joint function was impossible. In these cases, it was preferable and often practicable to excise the remaining articular cartilage. The remaining joint injury could then be likened to a compound fracture. By excision of the remaining articular cartilage, a poorly nourished and avascular potential nidus of sepsis was removed.

The immobilization was accomplished by means of a single hip spica or a Tobruk splint, with the knee in from 10 to 15 degrees of flexion. Systemic penicillin therapy was given routinely. Twenty-four to forty-eight hours after the initial surgery, with the use of a large needle, the synovial fluid was aspirated, and the joint was irrigated and filled with penicillin through a window in the cast, preferably without exposure of the open wound or the arthrotomy incision.

The plan of management was applied regardless of the time interval between occurrence of the wound and surgical treatment, or the presence of established sepsis. However, thorough excisional surgery within the joint was prerequisite to success.

B. *Base Hospital*

At the time of reparative surgery, four to six days after the wound had been received, the joint fluid again was aspirated, the cavity was irrigated, and penicillin was reinstilled.

The open soft-part wound was sutured. If reasonable doubt existed concerning the thoroughness of the initial operation, the joint was opened and examined as a precaution against sepsis (Case 1). Following thorough cleansing, the joint, and usually the skin, were closed. If reparative surgery was delayed for any reason, the joint fluid was aspirated through the window in the cast, while the patient was on the ward.

Immobilization was discontinued within ten to fourteen days after secondary suture, and active mobilization of the joint was instituted, usually by means of balanced suspension in a Thomas splint with the Pearson attachment. The motion was progressively increased from the position of full extension, thereby avoiding flexion contracture.

Signs of impending or of established sepsis within the joint—such as pain, swelling, fever, and malaise—were indications for early surgical treatment. Occasionally, in cases which presumably had been properly managed at the time of initial surgery and had minimum signs of infection, the aspiration routine was employed for a day or two with the anticipation of avoiding the impending sepsis. Otherwise the joint was opened widely, thoroughly cleansed of dead tissue and blood clot, closed, filled with penicillin, and immobilized (Cases 2 and 3). The skin was not sutured, but the edges often were freshened in anticipation of a staged closure, five or six days later. Frequent aspirations, irrigations, and reinstillations of penicillin appeared to be important in the subsequent care. Again, only when hope of a functioning joint was abandoned was the joint incision left open for drainage, and then radical resection was usually preferable.

RESULTS

Excellent results were achieved throughout the Theater when this program was followed[13]. From the beginning of the Cassino-Rome campaign, in May 1944, until cessation of combat, the incidence of knee-joint sepsis was negligible, and the problem was relegated to a place of relatively minor importance. In the few cases of early sepsis of the knee joint, observed in the base area, appropriate surgical treatment and management controlled the process, and usually good function of the joint resulted (Cases 2 and 8). Chronic sepsis rarely was seen,—usually only in joints hopelessly destroyed by trauma. In a study of Disposition Board Proceedings on a sample of 1,073 amputations, Rawles found none resulting from sepsis of a knee joint *per se*.

Knee joints which had been hopelessly destroyed at the time the wounds were received were usually resected to prevent chronic sepsis and to promote early healing of the wounds (Case 6). In the occasional case in which sepsis of the joint developed in the Base Hospital, the sepsis was controlled and wound healing was achieved by resection. The extent of bone loss and destruction incident to the sepsis or the trauma determined the amount of bone excised and the resultant shortening. The resected surfaces were designed so as to conform with the knee in extension, rather than in some flexion, because of the shortening incident to the procedure.

Data on Results

Harris and Mollin reported* that, in 128 patients with wounds of the knee joint who received complete initial surgery in forward hospitals, 119 were recorded as free of sepsis at the time of inspection in the Base Hospital; and repair of the remaining wounds of the soft parts was permitted. In seven of the remaining nine cases, sepsis was controlled and a functioning joint was obtained; only the aspiration routine was utilized in four cases, secondary arthrotomy and excision of the intra-articular devitalized tissue were carried out in two cases, and incision and drainage in one. In the remaining two cases the joints were the sites of severe bone damage, with superimposed sepsis. One case was managed, and the sepsis was overcome, by resection of the joint. In the other case, damage to the extremity was so severe that amputation was performed. The initial surgical procedure

* Data compiled in June 1945, from the records of the Seventeenth General Hospital.

was judged, from the records, to have been incomplete in sixty-six additional wounds of the knee joint seen at the same hospital. Among these, sixteen patients with septic joints were found at the first inspection. The sepsis was controlled in eight cases by arthrotomy and a secondary débridement of the joints. One patient, with associated severe bone damage, responded to prolonged drainage through an open wound, but it was questionable whether any joint function was obtained. In the remaining seven cases, the joints were hopelessly destroyed by the trauma received at the time of injury. Five were successfully managed by joint resection. The bone destruction was so severe in two that amputations were performed.

The Surgical Consultant of the Seventh Army, Colonel Frank Berry, who formerly was the Chief of Surgical Service of the Ninth Evacuation Hospital, instituted the same program of initial surgery in hospitals of the Seventh Army. From two General Hospitals supporting the Seventh Army, he received reports that, over a three-month period, no sepsis of the knees had resulted following adequate initial surgery[27]. The first hospital had received eighty-three consecutive patients with penetrating wounds of the knee, without the necessity of amputation, resection, or drainage. In a comparable number at the second General Hospital, only four resections were performed,—three for traumatically destroyed joints, and one for established sepsis; this developed in a patient with severe abdominal injuries and a penetrating wound of the knee, which had been overlooked during a ten-day stay in a forward hospital.

Disposition Board Proceedings on file in the Office of the Surgeon, Mediterranean Theater of Operations, on a sample of 271 wounds of the knee joint, were studied by Duncan and Rawles. The cases were divided into Group A, those occurring prior to May 11, 1944, and Group B, those occurring later. On May 11, the final drive for Cassino and Rome was begun and, by that time, information as to the recommended program for the management of wounds of the knee joint had been disseminated throughout the Theater.

TABLE I

	Number	Per Cent.
Group A (prior to May 11, 1944)		
Non-septic	53	72.6
Septic	20	27.4
Totals	73	100.0
Group B (after May 11, 1944)		
Non-septic	188	94.9
Septic	10	5.1
Totals	198	100.0

The incidence of sepsis after admission to the Base Hospital was 27.4 per cent. in Group A, but only 5.1 per cent. in Group B. The septic process continued and destruction of the joint resulted in 8.2 per cent. of the cases in Group A; the end results could not be determined in another 8.2 per cent. In Group B, however, the septic process was uncontrolled in only four cases (2 per cent.). In three of these cases, the management recommended for early sepsis was not instituted. In the other case, the damage was severe and resection of the knee joint was performed.

Twenty-four resections of the knee joint in American soldiers and one resection in a Canadian soldier are known to have been performed in the Mediterranean Theater of Operations. Two resections were performed at the time of the initial surgical treatment because of severe trauma; twenty-three were performed at the Base Hospital. In three cases, previously described, the indication for the resections of the knee, which were performed during the formative phase of the program, was severe purulent arthritis, superimposed on moderate intra-articular damage in two instances and on minimum damage

in another. In the remaining twenty cases, the indication was traumatic destruction of the joint with impending or early sepsis. Among the twenty-five Americans and six French patients[4] whose knees were resected, there were no deaths or amputations. The general condition of each patient improved rapidly. Healing of the wound was achieved in the majority of the Americans before their evacuation to the Zone of the Interior. Three are known to have had healed wounds and clinically stable knees prior to their departure from this Theater. The resultant shortening varied from one inch to three inches, *and was in direct ratio to the bone loss from trauma or sepsis.* The average shortening was about one and one-half inches. Apposition of bones in a functional position was achieved without difficulty.

The management of knee-joint wounds in all phases conformed to every principle of initial and of reparative surgery,—that is, the removal of foreign bodies and the excision of dead tissue, including the destroyed articular cartilage and the contaminated blood clot; closure of the joint to protect the articular cartilage from the hazard of exposure and the synovial membrane from recontamination; the use of antibacterial agents to protect living tissue from invasive infection; thorough immobilization, by means of a hip spica or Tobruk splint, until the hazard of infection was over; delayed wound closure; and early restoration of function.

This experience confirmed previous observations on the proper management of wounds of the knee joint, seen early and without infection. The same principles and plan of management have been adapted to wounds seen late and to those in which sepsis has become established. The success achieved warrants the recommendation of the program for wounds of the knee joint, regardless of the time which has elapsed since injury or the presence of infection. It is believed that the same principles are applicable to suppurative arthritis—traumatic, postoperative, or blood-borne—in civilian practice.

CASE REPORTS

CASE 1. This patient was wounded on March 26, 1944, by multiple small-arms fire.

Diagnosis

1. Compound, comminuted fracture of the distal third of the right femur, with laceration of the bursa of the knee joint;
2. Compound, comminuted fracture, incomplete, of the middle third of the right tibia;
3. Compound, comminuted fracture of the lower pole of the left patella;
4. Compound, comminuted fracture of the left medial femoral condyle.

Initial Surgery

Fourteen hours after the injury was received, all the wounds were debrided. The wound of the right thigh was perforating; that of the left knee was penetrating. A partially severed medial patellar retinaculum was repaired with a wire suture. Both joints were irrigated. A bilateral hip spica was applied.

Record at Base Hospital

The patient was admitted on March 31, five days after injury. Penicillin therapy, 25,000 units every three hours, was instituted. Blood transfusions, totaling 3,400 cubic centimeters, were given over a three-day period.

Reparative surgery was carried out on April 4. Arthrotomy of the left knee was done, using a medial parapatellar incision. The medial femoral condyle had been perforated. The devitalized articular cartilage, which had been driven in at the time of injury, was excised; and several small fragments of the patella were removed. After thorough irrigation, the joint was closed and penicillin was instilled. The skin was closed so as to leave a small fine-meshed gauze drain emerging from the lower pole of the compounding wound.

Through the compounding wound of the right lower thigh, it could be determined that no articular cartilage was damaged. Several loose chips of bone were removed from the fracture site. The joint bursa could be only partially closed. The medial wound was closed completely and the lateral wound was closed partially, drainage being established through the dependent pole. The compounding wound of the tibia was small, without exposed bone; it was not sutured. A toe-to-groin cast, with a horizontal cross-stick to prevent rotation, was used on the left. The right femur was placed in skeletal traction and the

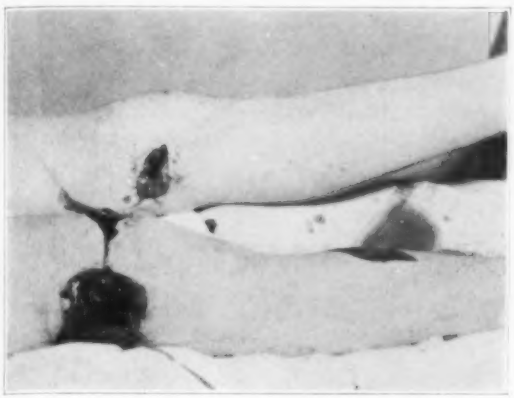

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. The wounds of each extremity are shown, as seen in the operating room on April 4, 1944.

Fig. 1-B: Arthrotomy of the left knee, demonstrating part of the intra-articular damage. A defect on the weight-bearing surface is not shown.

FIG. 1-C

FIG. 1-D

Fig. 1-C: Closure of arthrotomy incission and wound of left knee, and drainage of the knee with fine-meshed gauze. Penicillin is being instilled.

Fig. 1-D: Shows range of motion of left knee in June 1945.

fragments were manipulated into reduction on the ward, before the patient had recovered from the anaesthetic.

The wounds of the left knee healed. Immobilization was discontinued about May 1, after being used longer than is considered desirable. The range of flexion improved quite slowly, and was only 25 degrees when the patient was evacuated to the Zone of the Interior.

The wounds which connected with the right knee joint healed, but there was prolonged drainage from sepsis in the cancellous bone of the lateral condyle of the right femur. Despite the sepsis, the fracture united in good position. The knee joint was free of suppuration.

Record at Zone of the Interior

When the patient was admitted on September 8, there was profuse discharge from the site of the fracture of the right lower femur. All the other wounds had healed. The fractures of the femur and of the right tibia were stable. Knee motion on the left was from 180 to 130 degrees, but it was practically nil on the right.

After appropriate surgical treatment, healing of the compounding wound of the right femur occurred. On June 27, 1945, knee motion in the left side was from 180 to 90 degrees, and on the right side it was from 180 to 120 degrees.

Comment

By thorough management of the rather severe wound of the left knee joint, healing and over 90 degrees of knee motion were obtained. The dead space in the cancellous bone was the site of sepsis, but good drainage and maintenance of reduction of the fracture were followed by union of the fracture in good position. The end result was satisfactory.

CASE 2.* The patient was wounded on October 6, 1944, by a high-explosive shell fragment.

Diagnosis

1. Penetrating wound of the right knee joint;
2. Compound, comminuted fracture of the right patella;
3. Early suppurative arthritis of the right knee joint.

Initial Surgery

Ten hours after injury, the joint was opened by enlarging the wound compounding the comminuted patella, the foreign body was removed, the joint was irrigated, and the capsule was closed. The comminuted patella was not removed. Penicillin was instilled into the joint, and systemic penicillin therapy was instituted. A mid-thigh cast was applied.

Record at Base Hospital

The patient was admitted on October 11. Systemic penicillin therapy was continued, but the joint fluid was not aspirated nor was penicillin reinstilled. The patient's temperature ranged between 99 and 101 degrees. On October 20, the knee was painful, swollen, boggy, and tender. On October 21, the old wound was excised to the depth of the fascia. The joint was open through the fractured patella. A separate medial arthrotomy incision was used to expose the joint, from which a small piece of woolen cloth and the severely comminuted patella were removed. The cartilage of the patella was yellow and gray in color. One fragment appeared necrotic. Gelatinous fibrinous exudate was cleaned from the joint and from the suprapatellar pouch.

After thorough irrigation, the synovial membrane was closed, and a few sutures were placed in the quadriceps expansion. The defect in the tendon, at the site of the old wound, was closed. The joint was filled with penicillin. Immobilization was provided by a Tobruk splint. On October 22, 24, 25, and 26, the joint was irrigated and filled with penicillin through a large needle. On October 26, the skin of each wound was sutured. Penicillin therapy was discontinued on October 29. About November 7, active knee motion was begun, only night splinting being used. On November 17, all wounds had healed, the joint was not swollen, quadriceps power was fair, and 45 degrees of active knee motion was present.

FIG. 2-A

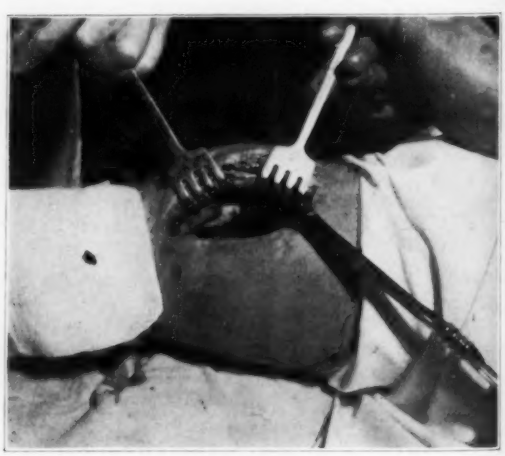

FIG. 2-B

Fig. 2-A: Case 2. Shows the swollen joint and the granulating wound, with pus draining from the opening in the center, as they appeared in the operating room on October 21, 1944, fifteen days after the wound had been received.

Fig. 2-B: Photograph of the medial arthrotomy incision. Inflamed synovial membrane and the partially necrotic cartilage of the comminuted patella are poorly visualized. The small piece of woolen cloth is shown on the gauze at the left of the incision. The quadriceps pouch was filled with a coagulated fibrinous exudate.

*This case was managed in the Base Hospital by Major John Abele of the Forty-Sixth General Hospital.

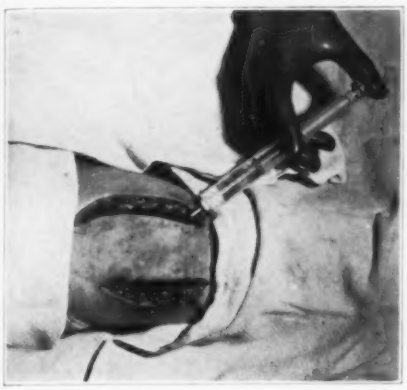

FIG. 2-C

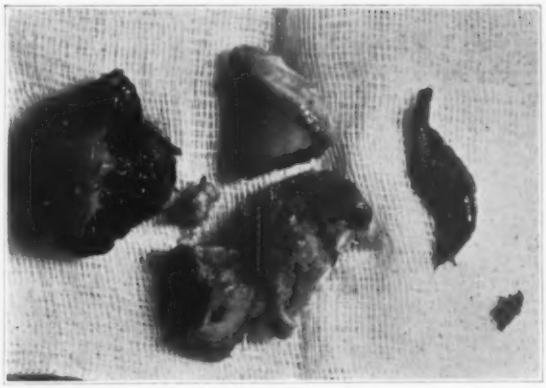

FIG. 2-D

Fig. 2-C: Following removal of the patella and cleansing of the joint, the synovial membrane of the arthrotomy incision and the defect in the old wound were sutured (plus a few sutures in the tendon). The joint was filled with penicillin.

Fig. 2-D: The fragments of patella, some of the fibrinous exudate, and the bit of cloth removed from the joint are shown.

FIG. 2-E

FIG. 2-F

Fig. 2-E: The skin has been sutured and the joint resplinted (October 26).

Fig. 2-F: Demonstrates the range of active painless motion of the knee on November 17. Quadriceps power was sufficient to extend the knee, but a hand held the foot for the photograph.

Comment

A compound, comminuted patella was frequently a nidus of knee-joint sepsis prior to the standardization of the Theater program for wounds of the knee. Traumatized cartilage remains, and, obviously, the joint remains open. The ineffectiveness of penicillin therapy when excisional surgery is inadequate should be noted.

In this case, removal of the comminuted patella and thorough cleansing from the joint of all foreign material, blood clot, and pus *before* proteolytic digestion of the articular cartilage began, followed by adequate immobilization and penicillin therapy, resulted in function of the joint.

This case is an excellent illustration of the management of *early* sepsis of the knee joint, which is a major contribution of this Theater in the management of wounds of the knee joint.

CASE 3. The patient was wounded on March 29, 1944, by multiple high-explosive shell fragments.

Diagnosis

1. Penetrating wounds of the left knee joint, left forearm and arm, and right foot;
2. Early suppurative arthritis of the left knee joint.

Initial Surgery

The wounds of the soft parts were debrided and foreign bodies were removed. For some unknown reason, possibly because of the multiplicity of the penetrating wounds, the knee joint was not opened.

FIG. 3-A

Case 3. Anteroposterior and lateral roentgenograms show the multiple foreign bodies in the joint.

FIG. 3-B

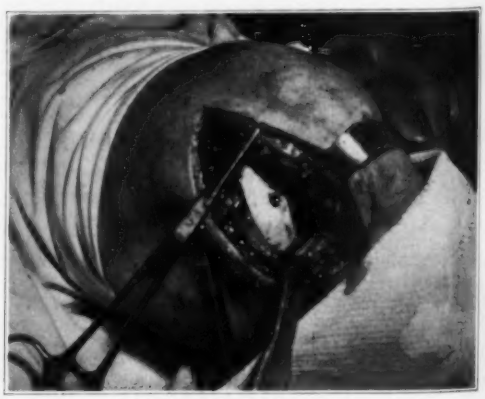

FIG. 3-C

Fig. 3-B: Photograph of the bulging knee, before surgery on April 11, 1944.

Fig. 3-C: Several areas of damage to the articular cartilage are revealed by the medial arthrotomy incision.

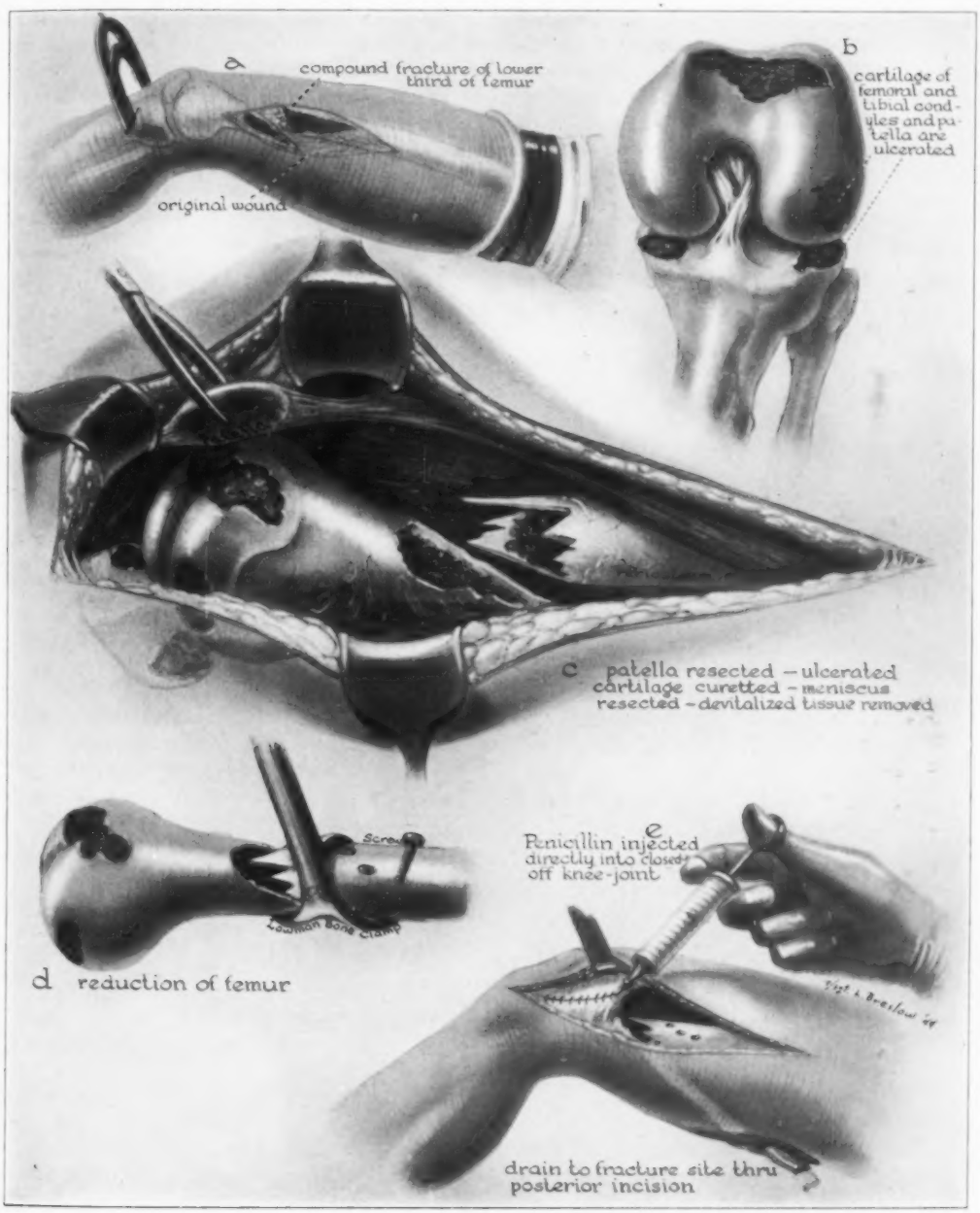
a
compound fracture of lower third of femur
original wound
b
cartilage of femoral and tibial condyles and patella are ulcerated
c patella resected – ulcerated cartilage curetted – meniscus resected – devitalized tissue removed
Screw
Lambotte bone clamp
d reduction of femur
e
Penicillin injected directly into closed off knee-joint
drain to fracture site thru posterior incision

FIG. 4

Case 4. Artist's conception of the surgical procedures carried out on April 6. The extent of bone loss is not shown. (*Reproduced, by courtesy of J. B. Lippincott Company, from Annals of Surgery,* **123**: 249, Feb. 1946.)

Record at Base Hospital

Upon admission, on April 8, the patient's temperature ranged up to 101 and 102 degrees. The knee joint was painful, hot, and swollen; and pus oozed from the multiple wounds. Penicillin therapy, 25,000 units every three hours, was instituted on April 9. On April 11, thirteen days after injury, the knee was opened through a medial arthrotomy incision. The bloody pus-filled joint was irrigated. Several imbedded metallic foreign bodies were removed from the articular cartilage of the femur. The medial meniscus was friable and partially devitalized; it was therefore excised. Through a lateral arthrotomy incision, areas of devitalized articular cartilage and a friable lateral meniscus were removed. After thorough irrigation, the synovial membrane of each incision was sutured. The joint was filled with penicillin

in a strength of 1 to 1,000, and a hip spica was applied. Through a window in the cast, the synovial fluid was aspirated, and the joint was irrigated and filled with penicillin daily from April 12 to April 16, and again on April 20. At the time the wound was dressed on April 20, the joint was not swollen and the synovial membrane had healed. The temperature had reached 100 degrees each day, but settled to a peak of 99 degrees on April 23. On April 26, the wounds of the soft parts were sutured; the wounds healed. On May 8, 30 degrees of active knee motion was recorded. The patient was evacuated to the Zone of the Interior in mid-May, with a removable night splint as a precaution against flexion contracture.

Comment

The sepsis following lack of initial surgery was controlled by excision of the intra-articular foci *before* the undamaged articular cartilage was digested and destroyed. Drainage incisions probably would have been ineffective. The Theater program for early sepsis was effective, and the optimum result for the given trauma was achieved.

FIG. 5-A

Case 5. Anteroposterior and lateral views, taken on March 22, show the erosion of the medial tibial condyle and the destruction of the entire joint.

CASE 4. This patient was wounded on February 20, 1944, by high-explosive shell fragments.

Diagnosis

1. Compound, comminuted fracture of the lower third of the left femur;

2. Low-grade suppurative arthritis of the left knee joint, secondary to laceration of the suprapatellar pouch and continued sepsis in a fracture of the femur.

Record at Base Hospital

On February 25, skeletal traction was instituted, with a wire in the tibial tubercle. The wounds were purulent at that time. Subsequently, several lat-

FIG. 5-B

FIG. 5-C

Fig. 5-B: Photograph of the joint, exposed at operation on March 26. The patella has been removed. For photographic demonstration, the patella is held beside the destroyed femoral condyles.

Fig. 5-C: Photograph of the resected joint. Shortening in this case was of no consequence, because of amputation of the opposite leg.

eral parapatellar incisions were made for drainage of the fracture site and the knee joint. On March 25, a pocket of pus was found in the proximal portion of the posterolateral fascial plane of the thigh. After admission, the patient's temperature had ranged between 98.6 and 104 degrees. On March 27, penicillin therapy, 25,000 units every three hours, was instituted. Blood transfusions of 1,000 cubic centimeters were given on March 28 and March 29; 500 cubic centimeters was given on March 30.

Reparative surgery was begun on March 31. At that time the posterolateral plane was incised, and the abscess and the fracture site were drained. Pus, which had tracked up the inner side of the thigh anterior to the adductor magnus, was drained by a medial incision. There was no union of the fracture. The extremity was returned to skeletal traction. A transfusion of 500 cubic centimeters of blood was given.

On April 6, through the compounding wound, the fracture was stabilized in reduction by four screws. The knee was opened by extending the incision distally. The articular cartilage of the patella was soft, eroded, and detached. There was spot erosion of the articular cartilage of the femur and tibia at points of contact, and at the place where the patella had rested upon the femur. The patella was removed. The edges of eroded cartilage were trimmed, and the bases were curetted. The joint was thoroughly irrigated, closed, and filled with penicillin. The wounds of the thigh were closed, with drainage. The extremity was returned to skeletal traction. A transfusion of 500 cubic centimeters of blood was given. There was moderate discharge from all wounds of the thigh for several weeks. All reaction about the knee subsided. After two weeks, passive motion through a

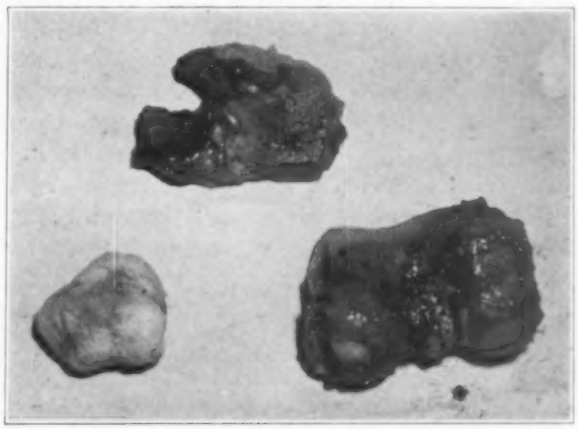

FIG. 5-D

The dead infected tissue has been excised.

FIG. 5-E

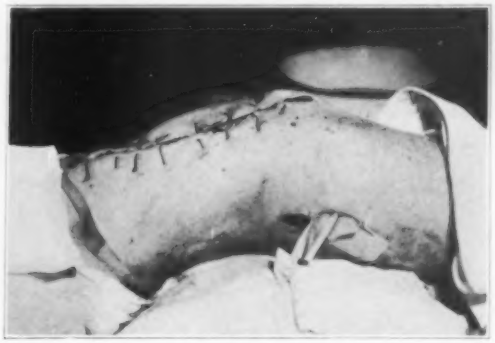

FIG. 5-F

Fig. 5-E: The medial wound has been partially closed, with drainage (April 1).
Fig. 5-F: Shows closure of the lateral wound and drainage of calf abscess (April 1).

FIG. 5-G

FIG. 5-H

The medial and lateral wounds have almost healed (no sinuses) on May 23.

10-degree arc was a daily routine. Only granulating areas in the old compounding wounds of the thigh remained when the patient was evacuated to the Zone of the Interior in May.

Record at Zone of the Interior

The fracture united, but it was necessary to remove two small sequestra and the screws before wound healing was achieved. Knee motion was limited to about 15 degrees. Unfortunately, in late December the patient fell and refractured his femur across the site of the bone loss. At the last report, he was still under treatment.

Comment

In the presence of abscesses tracking up the thigh on either side, an unreduced and non-uniting fracture, continuing destruction of the knee joint, and toxaemia of sepsis six weeks after the wound had been received, the prognosis was quite unfavorable. Drainage of the abscesses, excision of dead tissue in the thigh and joint, closure of the joint, reduction and stabilization of the fracture, and staged closures were followed by control of the sepsis, union of the fracture, and eventually, after removal of the sequestra and metal, by wound healing. Blood replacement and penicillin therapy were important adjuvants to the surgical treatment. The 10 or 15 degrees of joint motion which was achieved is preferable to the fusion which would have been anticipated with only drainage of the joint. The refracture in no way detracts from the achievement of the reparative surgery. It represents the hazard encountered in rehabilitation of patients with fractures of the long bones with partial loss of substance.

CASE 5. The soldier was wounded on January 8, 1944, by high-explosive shell fragments.

Diagnosis

1. Traumatic amputation of the upper third of the left thigh;
2. Compound, comminuted fracture of the medial condyle of the right tibia into the knee joint;
3. Multiple penetrating wounds;
4. Suppurative arthritis of the right knee joint.

Initial Surgery

Forty hours after injury, the traumatic amputation was completed by the guillotine method. Other wounds were debrided. Little was done to the penetrating wound compounding the fracture (almost invisible by roentgenogram) of the upper right tibia into the knee joint. The patient received 1,500 cubic centimeters of blood before and during operation.

Record at Base Hospital

After admission on January 21, the patient had continual sepsis. The amputation stump was clean, but there was profuse discharge from the upper tibia. On February 10, the knee joint was drained by bilateral parapatellar incisions. Penicillin, 25,000 units every three hours, was given intramuscularly for two weeks. Repeated blood transfusions were given. Sepsis continued, with fever up to 102 degrees. On March 3, roentgenograms disclosed total destruction of the medial tibial condyle. On March 9, a large abscess on the lateral aspect of the thigh, but connected with the knee joint, was incised. On March 12, systemic penicillin therapy was re-instituted. On March 23, the patient appeared quite ill, and amputation was considered as a life-saving measure. His temperature reached 102 and 103 degrees daily. Blood therapy in the Base Hospital totaled 4,500 cubic centimeters. On March 24 and 25, an additional 1,500 cubic centimeters was given.

At operation, on March 26, the old incisions on either side of the patella were extended proximally to drain abscesses of the thigh. Another abscess in the calf was incised. Lateral reflection of the patella disclosed that the joint cartilage, including that of the patella, had been totally destroyed by sepsis. The destroyed bone was resected, and the patella was removed. The bones were held in approximation by an anterior wire loop. The old wound edges were excised, but closure was not done. A hip spica provided immobilization. A transfusion of 1,000 cubic centimeters of blood was given during the operation, and 500 cubic centimeters was given on March 27 and again on March 28. The only temperature rise above 100 degrees during the first five days after operation occurred following a mild transfusion reaction. On April 1, the spica was removed in the operating room; the old blood clot was irrigated away; and the wounds were partially closed, with drains to the back of the old joint space and to the calf abscess. The blood given on this day totalled 1,500 cubic centimeters. On April 7, the abscess in the calf required further incision. On that day 500 cubic centimeters of blood was given. All drains were omitted, and the wounds were dressed with dry fine-meshed gauze. The wounds granulated to produce almost complete healing, and the knee fused to stability. The patient's temperature remained at 99 degrees or under.

Penicillin was discontinued on April 20. An interesting observation was that, in spite of the subsidence of his sepsis, the blood transfusions, and an increased appetite, the patient definitely appeared to lose weight,—a phenomenon attributed to the mobilization of abnormally retained interstitial fluid. Later he

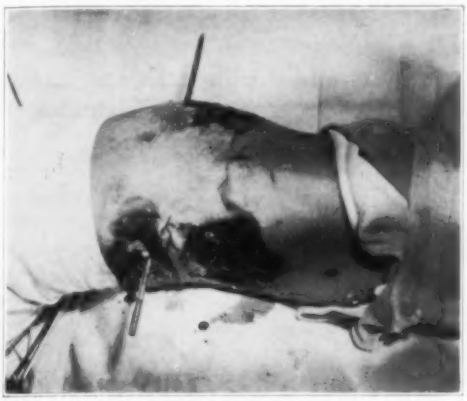

FIG. 6-A

FIG. 6-B

Fig. 6-A: Case 6. The knee is ready for surgery (April 24).

Fig. 6-B: The destroyed joint has been exposed. The possibility of restoring joint function was hopeless.

Fig. 6-C: Photograph of the resected articular surfaces of the femur and tibia. Note the destruction of articular cartilage.

Fig. 6-D: Lateral and anteroposterior roentgenograms of the resected knee.

FIG. 6-C

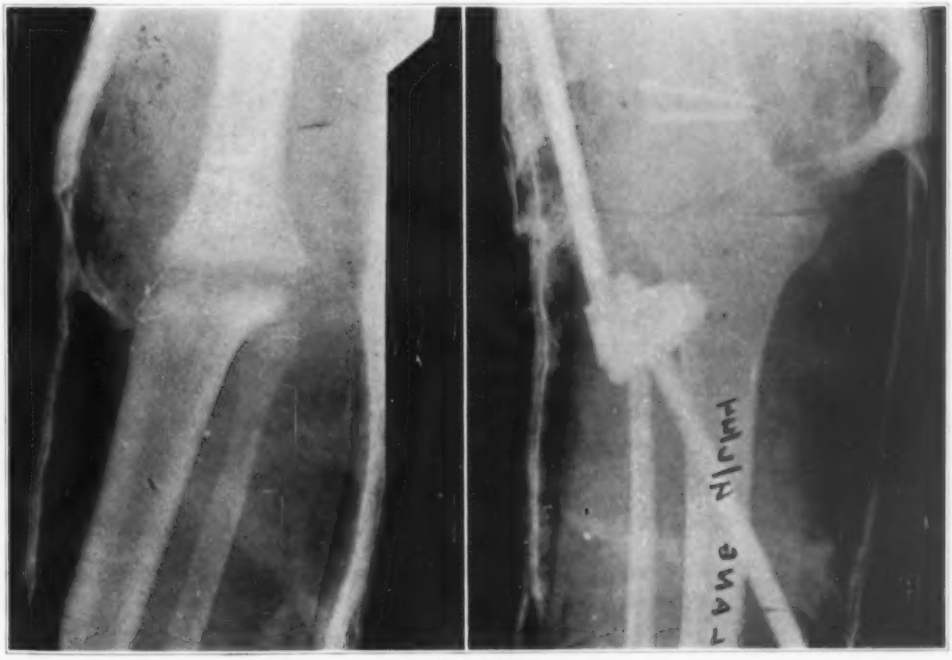

FIG. 6-D

gained weight and appeared well. He received a total of 12,500 cubic centimeters of blood over a three-month period. In late April, he was transferred to a Canadian hospital, and since then follow-up information has not been available.

Comment

The ravages and potential dire consequences of knee-joint sepsis, the ineffectiveness of drainage incisions, particularly after septic destruction of articular cartilage, and salvage of a limb and possibly of a life by resection of the knee, are illustrated in this case.

CASE 6. This patient was wounded on April 3, 1944, by high-explosive shell fragments.

Diagnosis

1. Perforating wounds of the right knee joint;
2. Compound, comminuted fractures of the right femur, supracondylar and condylar, the right patella, and the right fifth metatarsal;
3. Laceration of the patellar tendon;
4. Early suppurative arthritis of the knee joint, superimposed on severe trauma.

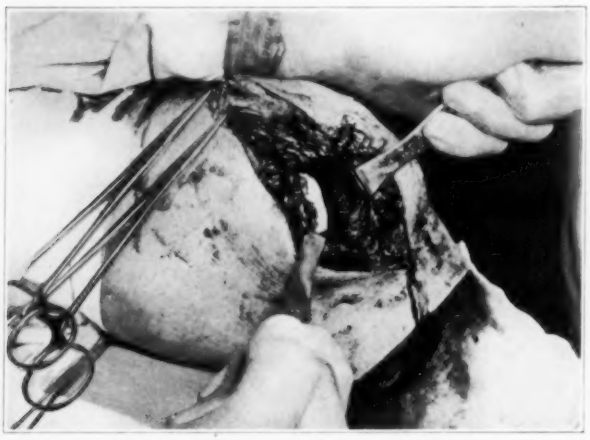

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 8. Photograph of the interior of the knee at the time of operation (July 14). The edge of the damage to the articular cartilage is visible. Note the intense hyperaemia.
Fig. 7-B: On August 7, the operative wound had healed and the joint was normal in size.

FIG. 7-C

FIG. 7-D

Fig. 7-C: Reproduction of anteroposterior roentgenogram, taken early in 1945. The extent of condylar damage is demonstrated.
Fig. 7-D: Shows the range of knee motion in 1945. Complete extension was possible, but is not shown here.

Initial Surgery

Following excisional surgery, which included removal of the comminuted patella, wire sutures were used to approximate the patella and the quadriceps tendons, and the skin flap over the knee was held in place by two silk sutures. A Steinmann pin was passed through the distal condylar fragments, presumably in an effort to avoid spread or rotation of the condyles. (The use of skeletal fixation in forward areas is not recommended.) The pin emerged through the wounds, medially and laterally.

Record at Base Hospital

The patient was admitted on April 14. The joint and the fracture site were bathed in pus. An effort was made to obtain reduction of the supracondylar fracture by joining the previously placed Steinmann pin to half-pins inserted in the femoral shaft by the apparatus of external skeletal fixation. Reduction was not achieved. Between the time of admission and April 23, the patient's temperature ranged up to 102 degrees. Systemic penicillin therapy, 25,000 units every three hours, was instituted on April 19. Between April 19 and April 23, the patient received 4,600 cubic centimeters of blood.

On April 24, three weeks after injury, in the operating room, it was determined that pus was oozing about the pin and from the knee joint. The pin was removed. Through a lateral incision, the supracondylar fracture was stabilized in reduction by two screws and a wire loop, in spite of some bone loss. Examination of the knee disclosed a hopelessly destroyed joint. The sutures previously placed in the skin flap and the patellar tendon were removed, and the articular surfaces of the femur and tibia were resected. The flap of skin was sutured in place so as to cover all exposed bone. Rubber drains emerged from the back of the joint, through posteromedial and posterolateral wounds. Half-pins were inserted in the tibia, and connected to the half-pins in the femur by the rods used in external skeletal fixation; fair fixation of the knee in good apposition was thereby achieved. A single hip spica was applied, which incorporated the apparatus. A transfusion of 1,000 cubic centimeters of blood was given during the operation. On May 3, through a sleeve resection of the cast, the drains were removed and the remaining wounds were prepared for a staged closure by excising the skin edges and the old granulation tissue. The external skeletal fixation was quite advantageous in maintaining stability during the surgical procedure. On May 8, a bit of protruding external condyle was chiseled away, and the wounds were sutured. Wound healing was achieved, except for a persistent sinus from the region of the supracondylar fracture. The patient was evacuated to the Zone of the Interior late in July.

Record at Zone of the Interior

The patient was seen by the Surgical Consultant of this Theater in January 1945; at that time there was firm fusion and wound healing, except for the sinus, which was recognized as reaching a sequestrum in the old internally fixed fracture.

Comment

The badly damaged extremity, with early sepsis, presented a problem in wound management. Obviously, full function could not be restored. The damage to the joint precluded hope for future motion of the knee. The internal fixation maintained length, stabilized the fracture, and permitted the knee-joint surgery. Removal of the avascular, necrotic tissue (the keystone of reparative surgery) obviated the hazard of sepsis and permitted procedures to achieve wound healing. Although an arthrodesis was performed, the objective of the operation was the control of sepsis, with wound healing,—not arthrodesis. The optimum result for this severe injury was achieved in a minimum period of time by application of the principles of reparative surgery.

CASE 7.* The patient was wounded about October 15, 1944, by multiple high-explosive shell fragments.

Diagnosis

1. A severe avulsing wound of the right knee;
2. Compound, comminuted fractures of the left humerus, radius, and tibia, and of the right femur (not considered here);
3. Paralysis of all nerve trunks of the left arm (not considered here).

Initial Surgery

The right knee joint and the lines of fracture of the femur, extending into the joint, were exposed because of an avulsion of the patella and expansion of the outer side of the quadriceps. Following thorough cleansing of the joint, a graft of fascia lata was utilized immediately to achieve a closed joint, and penicillin was instilled.

* The surgeon performing the initial surgery was Major Small of the Fifty-Sixth Evacuation Hospital.

Record at Base Hospital

This record was not available.

Record at Zone of the Interior

The patient was observed in March 1945, with a small unhealed granulating area over the old wound of the knee joint. The joint was freely movable through a range of 30 degrees.

Comment

The excellent initial surgery was the important factor in the salvage of the knee joint. Had the joint remained open, it probably would have been destroyed by sepsis and necrosis of the exposed cartilage.

CASE 8. The patient was wounded on July 1, 1944, by high-explosive shell fragments.

Diagnosis

1. Penetrating wounds of the left knee joint, arm, ankle region, and shoulder;
2. Early suppurative arthritis of the left knee joint.

Initial Surgery

Seven hours after injury, the knee joint was opened and a foreign body, embedded in the medial femoral condyle, was removed. The joint capsule was sutured. Penicillin was instilled into the joint; and systemic penicillin therapy, 25,000 units every three hours, was instituted. The patient was evacuated in a split toe-to-groin plaster cast.

Record at Base Hospital

The patient was admitted on July 6. The daily temperature range was from 98 to 101.4 degrees. The knee was painful and swollen, and pus was oozing from it. The joint was irrigated through a large needle, and 20 cubic centimeters of penicillin, in a strength of 1 to 1,000, was instilled on two occasions. On July 13, the patient's temperature was 101 degrees, and the knee was swollen, boggy, and tender. A seropurulent discharge leaked from the joint. Maggots crawled from the wound.

On July 14, the joint was opened through the old wound, plus a proximal extension. Maggots again were present. A piece of woolen cloth and, from beneath it, a devitalized area of articular cartilage about one inch in diameter, depressed into a defect in the condyle, were removed. The defect was trimmed evenly and the joint was thoroughly inspected for further damage, but none was found. The medial meniscus was dull in appearance, but it was not friable and so it was not removed. After thorough irrigation, the synovial membrane and the capsule were closed, and the joint was filled with penicillin. Immobilization was achieved by means of a Tobruk splint. A dirty wound of the ankle was debrided, but was not closed. Wounds of the shoulder were excised and sutured, with drainage. Systemic penicillin was continued. On the second and third days after operation, the synovial fluid was aspirated, and the joint was irrigated and filled with penicillin through a large needle. The temperature remained under 100 degrees for five days, and then under 99 degrees. On July 19, five days later, the skin was sutured; this left a gap in the center (because of tension) and also a raw area over the patella. Quadriceps exercises were instituted. Penicillin therapy was discontinued on July 29. On August 7, the wound was almost healed. Daily periods of knee motion, active and passive, were instituted. On August 22, it was noted that the joint reaction had subsided, quadriceps power was present, but only 10 to 15 degrees of flexion could be obtained. The shoulder wounds had healed. The patient was evacuated to the Zone of the Interior in September, with removable splinting for use at night as a precaution against flexion contracture.

Record at Zone of the Interior

On April 5, 1945, the patient was observed by a representative of this Theater at a Convalescent Hospital. All his wounds had healed, and knee motion was possible from extension to 100 degrees. The knee was reasonably stable, and the patient had no complaints other than his restricted motion.

Comment

This case illustrates the necessity for and the effectiveness of an aggressive surgical program in early knee-joint sepsis. Obviously, drainage alone would not have controlled the sepsis, or have prevented complete destruction of the joint. The excisional surgery was the most important factor in the achievement of the excellent result. With the pabulum for joint sepsis removed, and with penicillin therapy to protect living tissue from invasive infection, the remainder of the program was effective in avoiding recontamination, obtaining healed wounds, and promoting the early resumption of function. In the presence of inadequate initial surgery, penicillin therapy *did not prevent sepsis.*

CONCLUSIONS

1. At the time of the initial surgical treatment, the preferred plan of management for penetrating wounds of the knee joint—regardless of the time interval between receiving the wound and operation—should include arthrotomy; excision of the devitalized tissue, including areas of destroyed articular cartilage; cleansing of the blood clot and debris from the joint; suture of the synovial membrane or capsule; and immobilization of the limb in a hip spica or a Tobruk splint.

2. At the time of reparative surgery, preferably from five to ten days after the intra-articular surgery, the skin should be sutured.

3. Immobilization should be discontinued as soon as the danger of sepsis is past and the skin has healed, or is healing. Active and passive mobilization should then be instituted.

4. In cases of suppurative arthritis of the knee joint, potential or established, the same surgical plan is indicated.

5. Continuous drainage of fluid from the knee joint is not adequate surgical treatment in cases of suppurative arthritis; moreover, it is not indicated.

6. Systemic penicillin (at present the best available antibacterial agent), supplemented by the local instillation of penicillin into the joint, should be employed in patients with wounds and suppurative arthritis of the knee joint, in order to prevent invasive infection of the living tissue.

7. In the light of the problem and the hazards of knee-joint sepsis, knee-joint resection has a definite, but fortunately a limited, application in the management of severe wounds and sepsis of the knee joint in military surgery.

NOTE: This program was developed under the supervision of Colonel Edward D. Churchill, Surgical Consultant, Mediterranean Theater of Operations, United States Army; and in conjunction with Major Champ Lyons, of the Theater Consulting Staff, and Colonel Howard E. Snyder, Surgical Consultant, Fifth Army. The majority of the patients seen during the formative phase of the program were on the services of Major Joe M. Parker and Captain John J. Modlin, Twenty-First General Hospital; Majors Joseph Godfrey and Benjamin E. Obletz, Twenty-Third General Hospital; and Lieutenant Colonel George Duncan and Major R. D. Butterworth, Forty-Fifth General Hospital.

Acknowledgment for the illustrations used is made to Museum and Medical Arts Service, United States Army Medical Museum.

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SKIN-GRAFTING IN THE TREATMENT OF OSTEOMYELITIC WAR WOUNDS *

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During the past three years the writer has witnessed at close range the application of skin-grafting techniques to the healing and subsequent treatment of osteomyelitic wounds.[6,7] There is little basic difference between closure by skin grafts, either free or pedicled, and secondary or primary closure, as advocated and developed by Key, Dickson and his associates, Churchill, and Hampton during the War and the years which immediately preceded it. In some war wounds, loss of both bone and soft tissue is so extensive as to preclude secondary closure, and some other means must be sought for inducing prompt healing. Free skin grafts will often effect healing of such wounds.

At Ashford General Hospital this work has been carried out on an Orthopaedic Section manned by officers whose training has been in orthopaedic surgery, general surgery, or a combination of the two. A concerted effort has been made to satisfy the principles of skin transference, with especial reference to the avoidance of tension and the development and protection of the blood supply in pedicle grafts. In some instances the technique which could be applied to the task was inadequate to meet such basic requirements in the circumstances which arose. Obviously, these instances represent failures. These failures are in some measure offset by the prompt, good results obtained in the predominating group of successes, and by appreciation of the severe problems presented by some cases. Because of his tremendous backlog of battle casualties, the skill of the army plastic surgeon will not be available to many patients with osteomyelitis for several years. The orthopaedic surgeon, with an understanding of the basic principles of skin transference, but usually with little training in its details, will have to face some of these problems. It is the writer's intent to present an abstract of the experience of the group with which he has been associated in this work.

SAUCERIZATION

Saucerization is a traditional word. Like débridement, it fails to describe accurately what is performed, but will probably continue in use for lack of a better term. Not only all dead tissue, but also all devitalized tissue must be removed, and the contour of the wound must be such that subsequent application of appropriate pressure to a skin graft will be possible.

FREE SKIN-GRAFTING

After saucerization, if the wound does not admit of tensionless closure with suitable elimination of dead space, skin-grafting is needed. Occasionally a pedicle skin graft may be applied directly to a well-saucerized wound. More often, a free graft must be employed, although usually this is but a temporary measure. Application of a free skin graft is an excellent test of the adequacy of the saucerization, for, wherever necrosis exists in the bed, there one encounters failure of "take".

Optimum Time for Grafting: A number of skin grafts have been performed at the same time as saucerization. Others have been done as much as six weeks afterward. At present, the author prefers the interval of four days. Following saucerization, vital tissues

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

within the wound assume a coat of granulations. Necrotic tissues and those of low vitality fail to do so, and will not sustain a skin graft. An appraisal of the receptiveness of the wound to a free skin graft is based purely on its gross appearance. Under an appropriate pressure dressing, the granulations developing in a period of less than four days will be

FIG. 1-A

Result in severe arm wound with osteomyelitis of humerus, distraction, delayed union, and radial palsy.

Fig. 1-A: Appearance six weeks after being wounded by high-explosive shell fragment. Note necrotic bone in upper portion.

Fig. 1-B: Shows wound five days later, after saucerization and pressure dressing. Note generally healthy appearance; radial nerve is seen in anterior third of wound.

FIG. 1-B

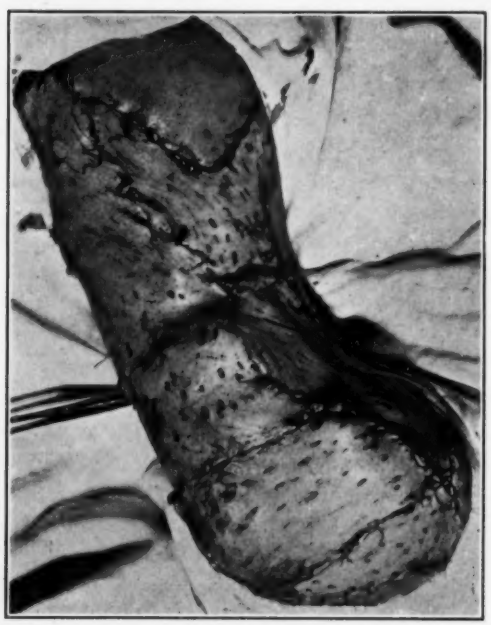

FIG. 1-C

Fig. 1-C: Skin graft has been sutured into place. Note close fit of graft to contours of wound.

FIG. 1-D

Fig. 1-D: Late result. Early "take" was better than 95 per cent.

FIG. 1-E FIG. 1-F FIG. 1-G

Serial roentgenograms show spontaneous union. Function returned to radial nerve in this patient.

too inconspicuous to permit of ready differentiation between vital tissue and that which is necrotic, or potentially so. When such tissue is found in the wound, further surgery is performed for its eradication, and a new pressure dressing is applied. This procedure is repeated until, upon removal of the dressing, one finds only healthy tissue. No attention is paid to the bacterial flora present. Other technical factors being equal, results have appeared to be proportionate to the health of the bed into which the graft was applied.

Thickness of Graft: Certain situations justify the hope that a successful free skin graft will afford stable coverage of the wound [7], and that subsequent treatment will be unnecessary. A graft 0.016 inch in thickness is probably ideal. A large number of grafts have been of this thickness, and the "take" has been excellent. Based on a few cases at Ashford General Hospital and on a number of Knight's cases, which the author has had the privilege of observing, it seems apparent that thin grafts make for more rapid stabilization of healing. Knight, believing that all free grafts should be replaced, favors thin ones.[9] Considerable slough is apt to develop when thicker grafts are used. Separation of this slough requires time and care during the postoperative interval. Once this process is complete, an excellent coverage is present, a large percentage of whose surface contains skin accessories. Lessened surface necrosis attendant upon the use of a thin graft leads to more rapid completion of secondary epithelization; it saves time and trouble, and helps the patient's morale.

PEDICLE GRAFTS APPLIED TO SAUCERIZED WOUNDS

Immediate application of pedicle grafts to saucerized wounds is feasible when saucerization has been thoroughly carried out and no potential dead space exists. Except for the abdominal variety, pedicle skin grafts can seldom be made available without advance planning. One is rarely able to predict in advance what the skin requirements will be after saucerization. Therefore, only in the upper extremity, and in but a few instances, has

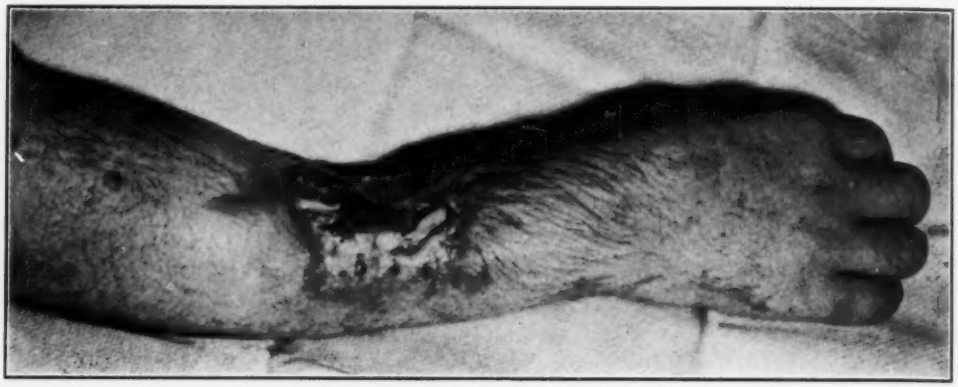

FIG. 2-A

FIG. 2-B

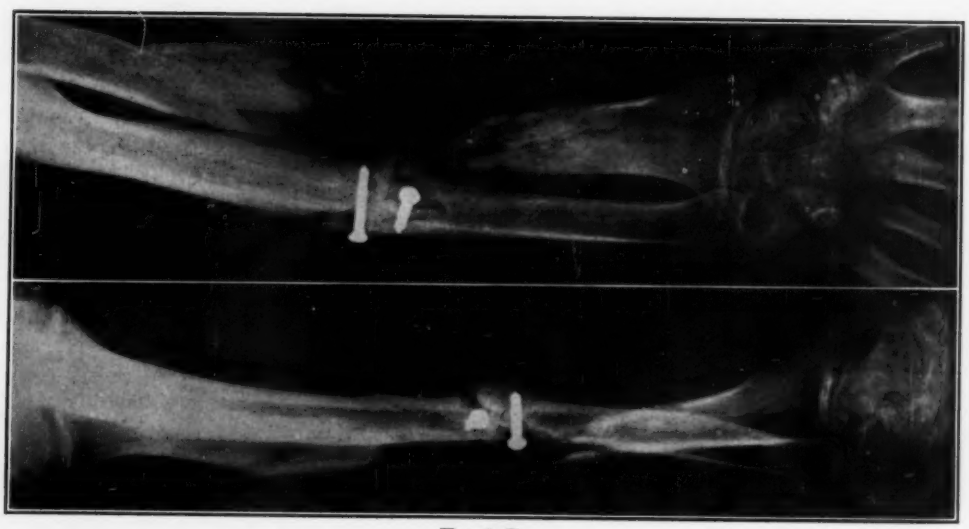

FIG. 2-C

FIG. 2-D

Wound treated by saucerization and early application of abdominal pedicle flap, by-passing dermatome graft.

Fig. 2-A: Photograph of original wound.

Fig. 2-B: Saucerized wound four weeks later, immediately prior to application of abdominal pedicle.

Fig. 2-C: Roentgenograms taken just before saucerization.

Fig. 2-D: Roentgenograms two months after application of pedicle.

Fig. 2-E: Roentgenograms taken after bone-grafting.

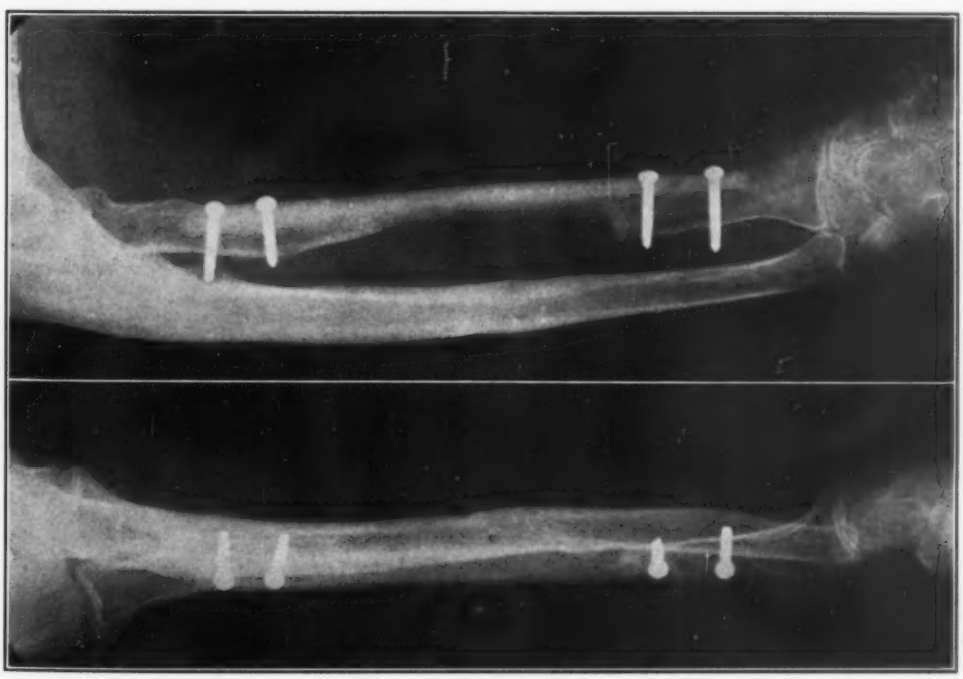

FIG. 2-E

the free graft been by-passed. Moreover, in the humerus presenting osteomyelitis with well-established non-union, healing of the fracture frequently follows saucerization, free skin-grafting, and immobilization (Figs. 1-A to 1-G). Thus we are left mainly with the forearm, upon which to practise direct application of the pedicle graft to the saucerized wound (Figs. 2-A to 2-E).

REPLACEMENT OF FREE GRAFTS

If replacement of a graft is anticipated, it is well to plan it at the time of saucerization. When a free skin graft is applied, the first stage in the development of any pedicle which is needed may be carried out. In some instances induration and oedema, persisting long after saucerization, preclude secondary closure. As surface healing progresses in response to free skin-grafting, however, local tissues become more pliable, and closure is practicable. After excision of the free skin graft, simple closure may be effected by approximation of opposing tissues, or it may be necessary to form some type of pedicle from local tissue.

Abdominal Pedicle Flaps: Abdominal pedicle flaps, as described by Brown, have been most satisfactory to repair skin defects of the arm and forearm (Fig. 3). If the pedicle is relatively wide, the flap can be based in any direction. At first a preliminary elevation was performed, and a free skin graft was placed beneath the flap a week before its initial application. Portions of these free grafts were lost through maceration and friction, and we now realize that most defects left in abdominal skin by transference of flaps can be closed by undermining and approximating the skin edges. Larger and more complicated flaps should be planned in advance. A stockinette pattern may be cut the shape of the area to be covered, although a little larger. The pattern, cut with a wide pedicle, may then be strapped to the abdomen with adhesive tape in various positions (Figs. 4-A to 4-E). Thus one can assure in advance an abundant blood supply at the base, a comfortable and readily maintained position of the arm during transfer of the flap, and a pedicle free of abrupt kinks or twists. The pattern may be sterilized with the instruments for use at operation.

FIG. 3

Representative abdominal pedicle flap. Note extreme width of pedicle, absence of abrupt twisting, kinking, or torsion, and comfortable position of forearm.

The wider the base with respect to length of the flap, the safer. The limit of safety for a flap, to be raised and applied in one stage, is in the ratio of two units of length to one unit of width of pedicle base. Where the base includes the epigastric vessels, this ratio can safely be exceeded somewhat. It is a good rule to proceed slowly, watching for the danger sign of cyanosis of the skin edges. If this is encountered before the flap is completely elevated, a delay of a week will be necessary. A corollary to this is that one should not denude the area to be resurfaced until a transferable flap has been assured.

Adhesive strapping serves as a satisfactory immobilizing agent for most abdominal pedicle flaps. It should be applied so as to discourage maceration and permit frequent dressings.

Cross-Leg Pedicles: The technique outlined by Ghormley and Lipscomb in performing cross-leg pedicles has been followed. Advance planning is again important, and may be carried out as explained previously. A preliminary outlining down to the deep fascia is

made by parallel incisions, a nearly complete undermining is done a week later, and a dermatome graft is placed beneath the pedicle at the end of the second week. With the use of the dermatome graft, "takes" have been excellent; and there have been no deleterious effects on the deep surface of the overlying pedicle. True, there has been fibrosis of this deep surface, which is resected when the flap is applied; but such a procedure seems necessary with any flap undermined at a stage prior to its application, and the necessity of performing it cannot be blamed solely on the dermatome graft. It is of considerable advantage to have the donor site already surfaced with skin at the time the pedicle is transferred. The end of the flap to be transferred is partially severed a week after dermatome grafting, and a few days later it is completely severed and initially applied to the recipient area.

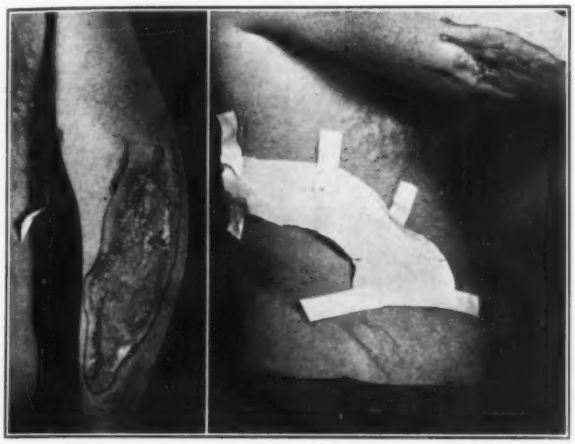

FIG. 4-A

FIG. 4-B

To avoid abrupt kinking and twisting of the pedicle, it is sometimes desirable to outline the flap obliquely, or even to base it distally

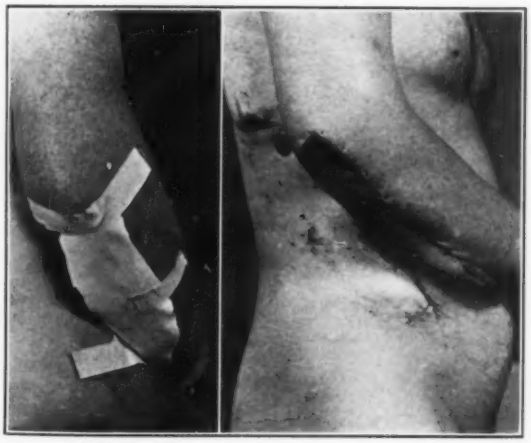

FIG. 4-C

FIG. 4-D

FIG. 4-E

Planning and execution of a large abdominal pedicle flap.
Defect (Fig. 4-A) and stockinette pattern held in place with adhesive tape (Fig. 4-B).
Pattern in position on arm (Fig. 4-C) and flap similarly placed (Fig. 4-D).
Fig. 4-E: Result.

instead of proximally. The farther the axis of the pedicle deviates from the normal direction of blood flow in the extremity, the greater the care with which it must be developed. If the base or direction of a cross-leg flap, prior to the initial application, is bizarre, partial severance had best be carried out in two or more stages.

Just before initially applying the cross-leg pedicle, the legs are placed in the intended position of application, and the position of the joints is noted. Plaster immobilization is applied to each leg individually, in order to maintain fixation in the position noted. Ample windows expose the pedicle and the area for resurfacing. After transfer of the pedicle to its new site, which is effected through stockinette draping over the plaster, one has but to join the two plasters by incorporating braces, making sure that no tension exists on the

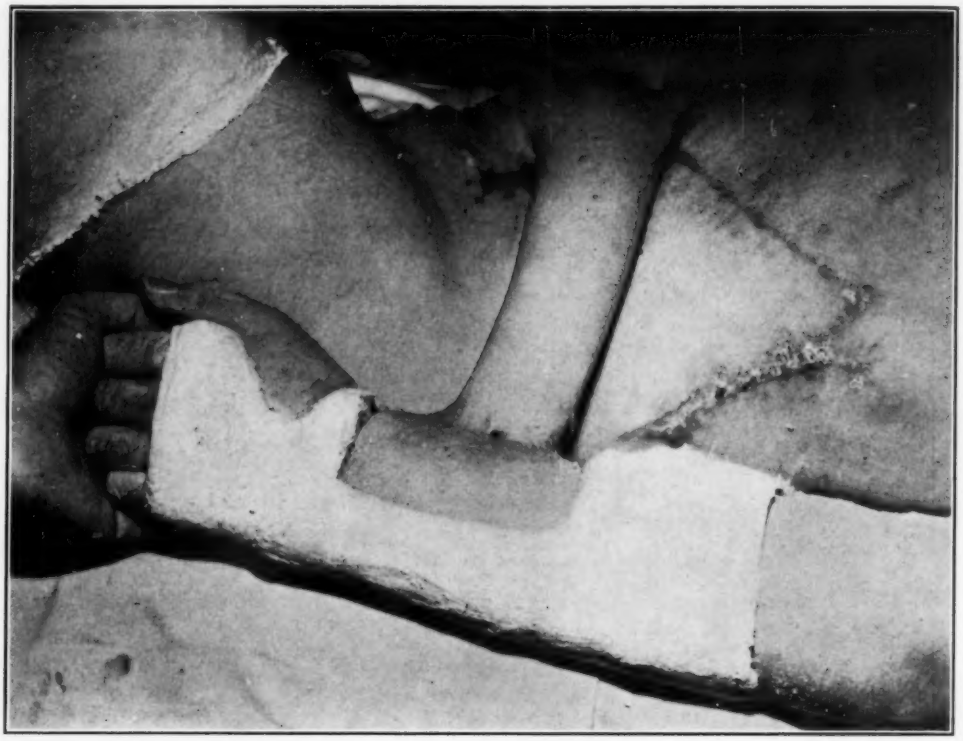

FIG. 5-A

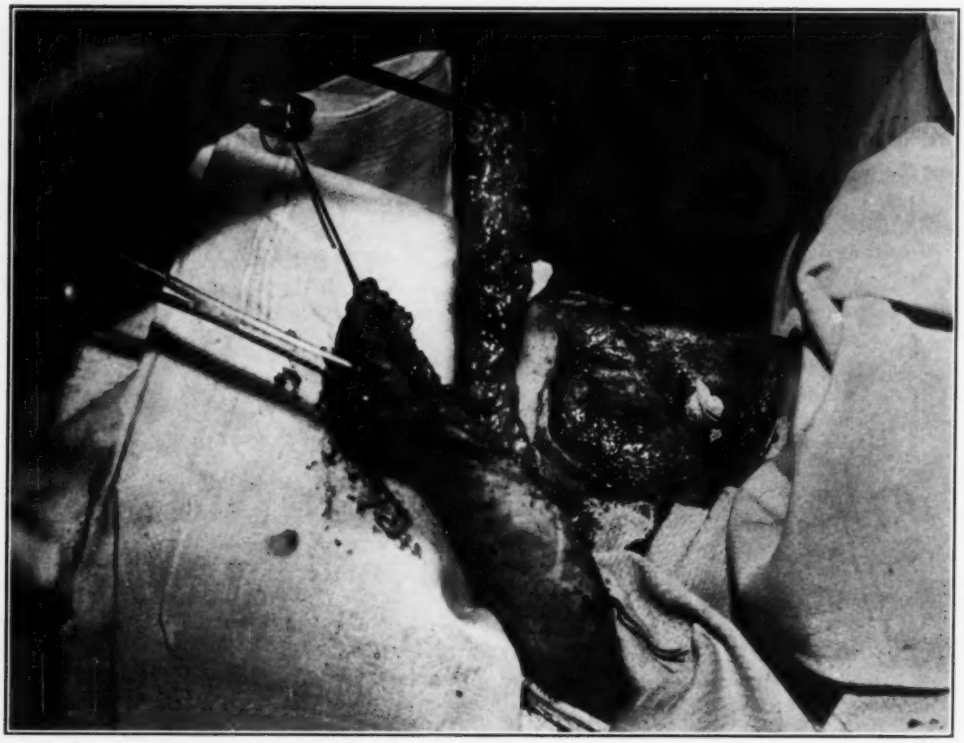

FIG. 5-B

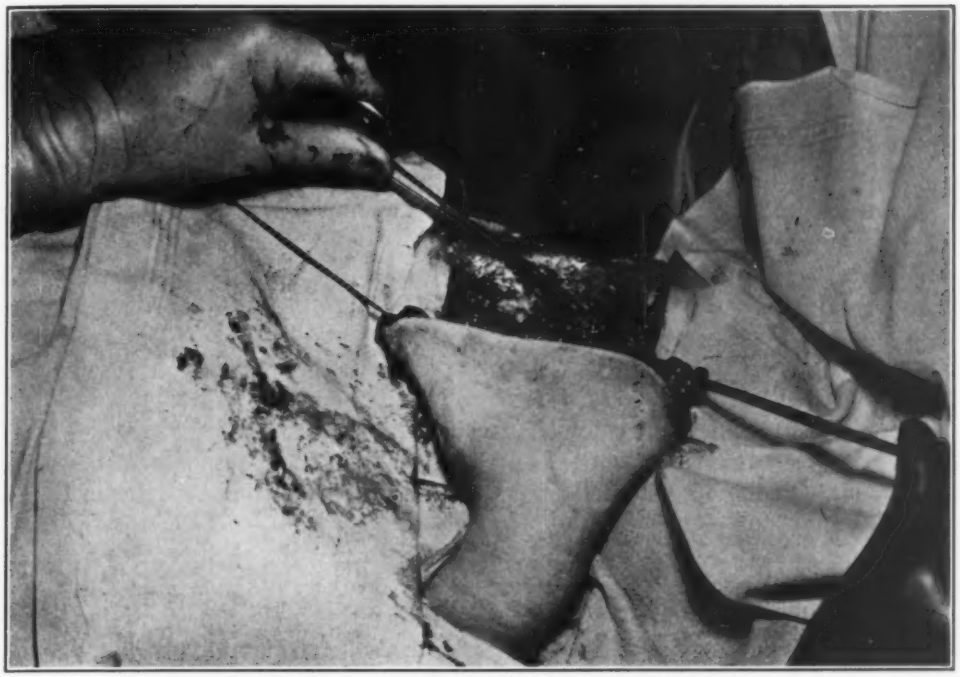

FIG. 5-C

Fig. 5-A: Pedicle of fat from large tube used to fill cavity. Note size of tube.

Fig. 5-B: Large pedicle of fat developed from tube, which is perhaps a little long for safety. Note tibial cavity with gauze sponge in its depth.

Fig. 5-C: Fat pedicle being led into cavity.

Fig. 5-D: Application of tube to wound. Because of the excessive length of its pedicle, the fat became necrotic after the final stage.

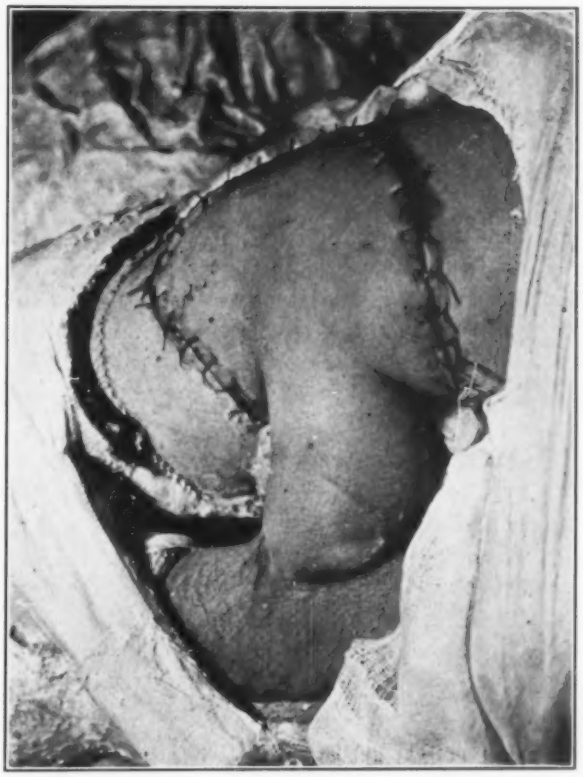

FIG. 5-D

pedicle. Whenever possible, a pedicle skin graft should be observed for circulatory changes in two hours, and again in twenty-four hours, after application. Minor adjustments may avert disaster; and, at times, immediate return of the pedicle to its previous site may be indicated because of poor circulation.

DEAD SPACE

The replacement of dermatome grafts, originally applied to saucerized osteomyelitic wounds by the process described, is practicable, provided the contours of the skin-grafted area present no potential dead space. All such space must be obliterated if one hopes successfully to effect replacement of the dermatome graft by pedicle skin transplants. Localized pressure or localized tension sutures, used in

an attempt to force the pedicle into dead space, jeopardize the circulation to distal points of the pedicle. To avoid this, one must eliminate cavities by some means which do not offer insufferable insult to tissues.

Autogenous Iliac-Bone Chips

The author has had dismal failure in attempting to introduce chips into bone cavities in these wounds; infection resulted in most cases. Knight and Wood have reported success. No explanation can be offered for these failures; iliac chips have been employed with success in less favorable circumstances. Other means have thus been sought for dealing with cavitation.

Tubed Pedicles

One alternative to iliac-bone chips for filling these cavities is fat brought in with a tubed pedicle of skin. The fat can be "inverted" into the cavity in various ways (Figs. 5-A to 5-D), care being taken to maintain its blood supply intact. Where the cavity is excessively large and steep, a tremendous tube may be required, and here this method finds its greatest limitation.

Although the two-to-one ratio of length to width may be slightly exceeded in most tubes with safety, there is little to be gained from it in these patients. Later extension of the pedicle, either by a "paddle" or by further tubing of skin, is more feasible. After two weeks, the end of the tube for transference is pinched off for increasingly long periods, up to a half hour, with minimum color change indicating good circulation.

Most of the trouble with tubes has arisen from shortcomings in that sphere with which orthopaedic surgeons should be most familiar,—namely, immobilization. When tubes are transferred, the suture line must be protected from tension and excess mobility, and the entire tube from kinking. During transfer to the wrist, a plaster body jacket fixing the shoulders and hips has been found most satisfactory. This is joined by braces to a plaster, which maintains the wrist in cock-up position and the elbow flexed as much as the position of the tube permits. The angle of approach of the tube to the wrist, which can be controlled at this stage, should be planned so as to minimize kinking at the next stage; and forethought results in placing the eventual position of the suture line so that the tube need not be subjected to torsion, when transferred. The window in the arm plaster, through which the tube passes to its suture line at the wrist, must be ample to avoid impingement on the tube. For the same reason, the extremity must be fixed firmly in the plaster by dorsiflexing the hand and flexing the forearm. These principles of immobilization should be adapted to successive stages of transplantation of the tube, and rigidly observed.

Methyl Methacrylate

Captain E. R. Zaglio, of the Orthopaedic Section at Ashford General Hospital, has recently used implants of methyl methacrylate as a filler of dead space in the wounds under discussion. Several patients have been treated in this fashion. Skin to cover the acrylic has been taken from practically every source mentioned in the foregoing discussion, and prompt healing has resulted in each instance. It seems reasonable to hope for success in replacing these implants with bone after a time; likewise that in certain instances this rather inert substance may be left in place indefinitely.

SUMMARY AND CONCLUSIONS

Techniques of plastic surgery can be applied to the treatment of certain types of osteomyelitic wounds. Success in producing healing by free skin-grafting has been considerable. Later stages of reconstruction in these instances have succeeded, often in proportion to the operator's facility in performing pedicle skin transplants. In replacing free

skin grafts with pedicles in this group of patients, dead space presents a major problem. Contrary to the experience of others, attempts at Ashford General Hospital to fill such cavities with iliac-bone chips have resulted in a high proportion of infection; and other filling materials have been used, with varied success.

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DISCUSSION

Colonel Leonard T. Peterson, *Medical Corps, Army of the United States*: My experience with the technique described by Colonel Kelly has been limited to observation of the orthopaedic surgery at a considerable number of Army hospitals. In the early months of the War, it was customary to treat chronic osteomyelitis for long periods with plaster and infrequent dressings. Often the surgeon was reluctant to carry out the surgery required for adequate drainage and removal of sequestra. I am glad to say that a more aggressive attitude has been taken in recent months, with the excision of sequestra and other devitalized tissue, followed by early skin-grafting. Secondary closure of these wounds, without preliminary skin-grafting, has not usually been successful. The development of early saucerization, followed by skin-grafting, parallels closely the early secondary closure of compound wounds, as developed especially in the Mediterranean Theater and later practised in all theaters.

The method presented today represents one of the most important developments in reconstructive surgery of the War. Colonel Kelly deserves praise for his careful and honest evaluation of his results. Colonel Knight has recently published his outstanding results in bone-grafting the large defects which remain after skin-grafting. The orthopaedic and surgical consultants have contributed toward encouraging improved methods.

RESTORATION OF BONE STRENGTH WITH REINFORCEMENT BONE GRAFTS *

BY LIEUTENANT COLONEL GEORGE K. CARPENTER, MAJOR ROBERT T. ROSENFELD, AND MAJOR KARL F. MECH

Medical Corps, Army of the United States

Frequently a fracture progresses to union of such limited extent that full function should not be permitted because of the danger of refracture. This condition of bone healing occurs most frequently after severe compound, comminuted fractures of the long bones, particularly if there is an associated loss of bone substance. The authors have called this status of insufficient fracture healing by the descriptive term of "limited union". It has been found possible to restore bone strength and substance by the application of autogenous bone grafts, thus reinforcing the site of limited union sufficiently to permit earlier and unprotected use of the extremity.

The condition called limited union is not to be confused with delayed union. Delayed union progresses to solid bony union in due time, and the end result is compatible with normal function. Limited union is actually a condition of solid bony union; but the end result is a shaft which is incapable of normal function, since it is weaker and usually smaller than normal. The protected use of the extremity, such as with the prolonged use of a brace, does not, as a rule, stimulate increased bone substance at a sufficiently rapid rate to justify such a conservative procedure.

Limited union may manifest itself in various ways. The fracture may be united by bridging callus, with no evidence of union between the fragments. A comminuted fragment may bridge a large bone defect and solid bony union may result, but the fragment cannot possibly increase sufficiently in size and strength to permit unprotected use of the extremity. Another type of limited union is seen frequently following the loss of a large comminuted fragment which does not include the whole circumference of the shaft, and in these cases the shaft is rendered smaller in size at the site of union. Since severely compound, comminuted fractures often become infected subsequently, healing occasionally results in sclerotic bone which is not so strong as normal bone. Limited union is also seen occasionally after simple fractures.

There is no claim to originality in the reinforcement of the site of limited union by bone grafts for the purpose of quickly strengthening the fracture site sufficiently to permit normal function. One of the writers (G.K.C.) employed such a procedure as long as twenty years ago; but it was not until World War II that the operation was done in large numbers or without having first used a walking brace for many months in the vain hope that a larger and stronger fracture repair would develop. In the early days of this War we were inclined to delay; and, in so doing, many valuable days were lost. A few patients on furlough were sent to Halloran General Hospital following refracture, and roentgenograms often showed that the fracture had occurred at the site of limited union. Refracture occurred in two of the authors' patients while they were in the Hospital, in spite of awareness of this problem and vigilance in protecting the extremity. A compound, comminuted fracture is likely to require a long period of treatment, and early recognition and grafting in cases of limited union will very materially lessen the length of time necessary to effect recovery. All patients showing by roentgenogram the early manifestations of limited union are possible candidates for a reinforcement graft. It has always been the authors' policy to delay a bone-graft operation until three months after complete wound healing, in order to minimize the incidence of infection. The extent of bone healing at this time will nearly always

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

indicate whether the fracture will progress to a complete and sufficient union by conservative measures.

The first operation performed at Halloran General Hospital for limited union took place on November 26, 1943.

On March 30, 1943, the patient had sustained a severely compounded, comminuted fracture in the upper third of the shaft of the right femur. He was admitted to the Hospital on April 30. The plaster

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Limited union of femur, six months after injury.
Fig. 1-B: End result after operation.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 3. Severe compound, comminuted fracture of the femur, with limited union.
Fig. 2-B: Result after bone-grafting for limited union.

FIG. 3-C

Three months after bone-graft operation.

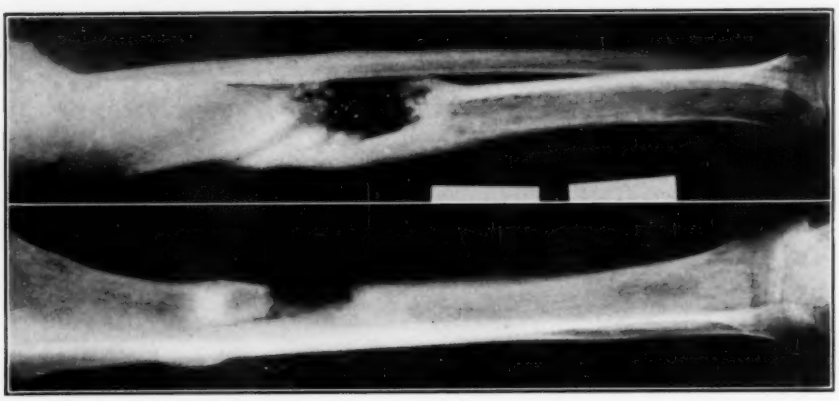

FIG. 3-B

After sequestrectomy, showing limited union.

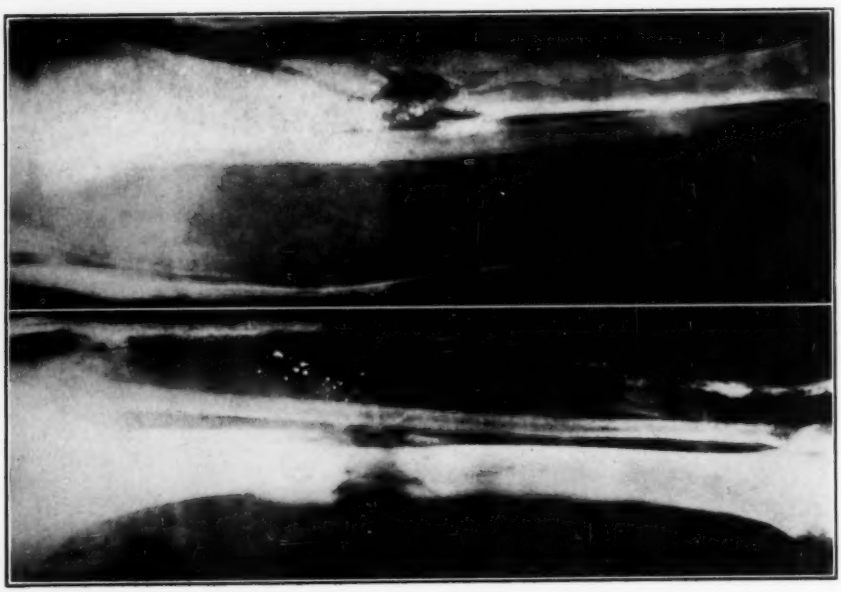

FIG. 3-A

Case 6. Severe compound, comminuted fracture of tibia, prior to sequestrectomy.

cast, which had been applied in Africa, was immediately removed, and the limb was put in suspension-traction. The patient had also sustained a compound fracture of the left radius. Both wounds healed promptly. Clinical and roentgenographic examinations made four months after the injury showed bony union, but the roentgenograms revealed so much loss of substance at the fracture site that it was believed necessary to continue the use of traction. After four months of traction, the roentgenographic findings were unaltered, and a reinforcement bone-graft operation was performed. This patient could have been operated upon three months earlier, as wound healing had occurred in less than two months after the

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 7. Showing defect of tibia; limited union is present. Prior to bone-graft operation, the scar tissue was removed from the bone defect, and the cavity was obliterated and covered with a full-thickness skin graft.

Fig. 4-B: End result, following bone-graft operation.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 9. Showing limited union of humerus, following a severe compound, comminuted fracture which became infected. Notice dense sclerotic bone.

Fig. 5-B: Anteroposterior and lateral views, after bone graft. Note that osteotomy was not performed to improve the mild angulation at the site of fracture.

injury, and he had suffered very little infection. Limited union was not recognized early, and, in consequence, the operation was performed at the end of eight months. The end result, however, was as follows: no deformity, no shortening, no limitation of joint motion, and, finally, excellent function. This patient remained in traction for more than ten months, but fortunately he was confined in plaster for only the first month after injury.

Well-supervised physical therapy, which included an effective exercise program to preserve muscle tone and joint motion, did much to hasten the restoration of function in this and similar cases.

From November 1943 to September 1945, a total of fifty-two operations for limited union were performed at this Hospital by reinforcement bone grafts. The bones requiring operation were as follows: femur, nineteen cases; tibia, eleven cases; first metatarsal, one case; humerus, eleven cases; ulna, six cases; and radius, four cases. These operations were performed by the various members of the Orthopaedic Section; the writers either performed or assisted in the majority of the operations. Tibial grafts with multiple chips and cancellous bone from the upper tibia were used in most cases. Iliac grafts may be used advantageously. Since in these cases union is present, even though it is not strong, it is unnecessary to employ extensive internal fixation of the graft, nor is external splinting always necessary. The extent of the limited union will help to determine the character of the fixation of the tibial graft and the type of external splinting. As a general rule, screws are used to fix the graft; and plaster casts are used for external fixation, except for the femur, which is almost always treated postoperatively in suspension-traction.

No new operative methods are presented, as it is believed that any type of sound grafting will be effective. Naturally, a sufficient amount of bone must be used to effect strong bony union. Penicillin therapy has been used, both before and after the bone-graft operation. The prerequisites for bone-graft surgery, which have been recorded by the authors and by such other writers as Brown, Lyons, and Murray, demand meticulous preoperative and postoperative care, both of the patient and of the involved extremity. When the patient and the extremity have been properly prepared for bone-graft surgery, the incidence of complications will be very low and excellent operative end results will be obtained. In one patient a previous infection flared up, but it was controlled quickly; and the case progressed to good bony union after removal of the screws and a small portion of

FIG. 6-A

FIG. 6-B

Fig. 6-A: Case 13. Roentgenograms show limited union of ulna.
Fig. 6-B: Roentgenograms show final end result after bone-graft operation.

the graft, which had sequestrated. It has been possible in all instances to restore bone size and strength sufficiently to permit unprotected function following reinforcement bone-graft operations for cases of limited union.

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DISCUSSION

Dr. W. W. Plummer, Buffalo, New York: As Civilian Consultant to the Orthopaedic Sections of the General Hospitals of the Second Service Command, it has been my privilege during the past two and one-half years to make frequent visits to Halloran General Hospital. As a result of those visits, I have had the opportunity of reviewing personally much of the material presented by Dr. Carpenter. Some of these cases I have seen through to the stage of end results. I would like to say that, under the conditions described in the speaker's presentation, the procedure has my wholehearted approval. I am sure, from what I have seen, that a protracted recovery period has been materially shortened, and a functional end result has been obtained, compatible with the type of original injury and superior to the end results expected from our previous experience with similar cases.

My personal observation of the cases upon which this presentation is based has led me to make two comments. The first is that, watching the progressive changes noted in a series of roentgenograms throughout the recovery period of any one of these cases, it seems to me that the bone graft itself and the adjacent bone structures show a remarkably rapid vascularization and trabeculation, and increased bone bulk. My own opinion is that, where there is solid union, the osteogenetic activities of the graft material are hastened.

My second comment refers to this same problem, in relation to the ununited fractures of the shafts of long bones. In 1932, at Toronto, I presented some twenty-odd cases of non-union of fractures of the shafts of long bones. Those cases were in a way analogous to the material under discussion, because all the patients had been through a series of one or more reconstruction procedures. All the fractures had failed to unite, and some of them had been complicated by infection. All of the cases of that series were treated by internal fixation (plating) plus osteogenetic material of some sort,—onlay, inlay, or chip grafts, or osteoperiosteal ribbon, as the individual case seemed to demand. My thinking at that time was based on a maximum amount of positive fixation with a minimum amount of surgical trauma. Thus I favored the plates and bone grafts, as against single or multiple massive grafts, which required extensive soft-tissue stripping to permit application of enough bone-graft material to supply adequate fixation. This produced minimum disturbance of existing blood supply in an already extensively traumatized area. In all of those cases the fractures progressed to functional union.

The point I am trying to make is that, in the light of the material so ably presented in the paper under discussion, we might well consider the desirability of the addition of internal fixation by an inert metal, with the expectation of more rapid healing and a consequent shortening of the recovery period, in our civilian cases of ununited fractures.

Colonel Robert H. Kennedy, *Medical Corps, Army of the United States*: As Consultant Surgeon, Second Service Command, I have had the opportunity of observing many of the patients at Halloran General Hospital upon whom the essayists performed these reinforcement bone grafts. The importance of the subject is far too little recognized. In fact, it would appear that many surgeons have never heard of it.

The possible later application of this procedure is one of the excellent arguments for maintaining proper length and axis, even in the presence of a large bone defect. On several occasions at Halloran I have seen perfect length and axis with a bridge less than a quarter inch in diameter across a wide defect. A reinforcement graft is not so formidable a procedure for this patient as is a graft for a complete defect. Less exposure and manipulation are required to prepare the bed; complete internal fixation is obtained with less hardware; and a much shorter period of immobilization after operation is required. Constant supervision of proper traction in the large defect is as important as in any other case.

It has not been uncommon to see patients, sent to the Convalescent Hospitals for reconditioning from General Hospitals all over the country, with union so limited that it is hard to imagine why the bones have not refractured long before, after the braces were removed. Apparently the surgeon has been so pleased to get bony union that he has forgotten that, if union exists in one half the diameter in each of two right angle planes, it means that a 25 per cent. volume of bone is called upon to do the work of 100 per cent. This is mature bone or sclerotic bone, and in either instance it will increase in diameter but little, since it is already surrounded largely by scar tissue. The time to have reached the decision that more bone would be required was within three months after wound healing; further delay in most instances entails useless confinement for the patient. Refracture means starting over again, with a poorer chance than the first time.

If the original strut has any strength before the reinforcement graft is applied, the time of external immobilization or traction can be markedly diminished afterward. Many patients will need no more than two or three weeks,—that is, until good wound healing has been obtained. If this volume of bone was sufficient to permit the patient to walk before operation, there will be no particular strain at the site of an onlay graft; and after a few weeks even the position of chips will change but little. This fact overcomes one's hesitation to immobilize the joints a second time for a prolonged period. The main requirement, however, is to give the patient a sufficient amount of strong bone to support him safely the rest of his life,—not merely until he is out of the surgeon's hands.

THE SURGICAL PRINCIPLES OF SPLIT-THICKNESS-SKIN GRAFTING

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INTRODUCTION

Plastic repair of lost integument does not lie in the domain of the plastic surgeon alone, but also comes within the sphere of the orthopaedic surgeon. Little is gained by restoring the continuity of a bone and preserving the integrity of a joint, if deformity and loss of functional activity result from scar tissue.

There is no doubt that early replacement of skin loss decreases mortality, morbidity, and the cost of illness, and prevents disfiguring scars, deformity, loss of function, and the occurrence of unsuitable weight-bearing surfaces.

John Staige Davis, in discussing a paper[24] read before the American Surgical Association in Chicago, May 3, 1944, stated: "It has been my observation over many years, that skin grafting, although a fairly simple process in the hands of those who know how and when to use it, is more consistently bungled than almost any other surgical procedure."

Although the author claims no originality for the methods advocated, and recognizes that this paper does not deal exhaustively with the many problems confronting the surgeon who contemplates restoration of lost integument, he will attempt to present those factors which have given him the most satisfactory results and which he believes to be basic surgical principles in the rational treatment of those cases which can be treated by split-thickness grafts. Skin-grafting requires infinite attention to multitudinous details of technique, the utmost gentleness, and intimate understanding of wound-healing processes. It should not be a fortuitous occurrence, since its success can be assured by an understanding of the surgical principles involved.

Contributions advocating new techniques have been so numerous in the medical literature in recent years that the casual operator is frequently bewildered as to the method to be used. This contribution was conceived with the view of presenting sound surgical principles for the basis of indications for the split-thickness graft.

HISTORY

The practice of tissue transplantation dates back to antiquity. The East Indians and Egyptians performed rhinoplasties 3,000 years before the Christian Era by the use of a pedunculated flap from the forehead.

Although Tagliacozzi at the University of Bologna, in 1597, is credited with founding the Italian school of rhinoplasty, by his own writings he concedes that his method of repair was based upon the teachings of Branca, a Sicilian surgeon of the year 1442. Following Tagliacozzi's death, plastic surgery fell into disrepute because of the influence of the church; and very little progress was made until the Nineteenth Century.

With the ebb and flow of civilization and learning, Carpue, a London surgeon, revived the Indian flap method of transplantation in the year 1816. Concurrently, Dieffenbach in Germany started transplantation experiments in animals. Although fickle history has placed the mantle of recognition about the shoulders of Jacques Louis Reverdin, a Swiss of French ancestry, as the first to transplant a small piece of skin in 1869, Dieffenbach was the first to succeed, in 1824. Similarly, although Louis Xavier Ollier contributed a paper in 1872 on the successful transplantation of a sheet of thin skin and Carl Thiersch's first paper on a similar result appeared in 1874, yet it was George Lawson of London who reported the first successful attempt on November 11, 1870.

* Service of Arthur Steindler, M.D.

John Reisberg Wolfe published the first paper on full-thickness grafts in 1875, and a few years later Fedor Krause reported on over 100 successful full-thickness grafts.

The full flood of the advance of plastic surgery was reached at the turn of the century. Goldmann, in 1893, and John Staige Davis and Traut made notable contributions to our understanding of the mechanism by which grafts "take". Davis introduced the deep pinch graft, which was a decided improvement over the Reverdin graft; although its application in modern skin transplantations is very limited in scope, it still has a place in the treatment of skin loss in debilitated patients and in those whose wounds are grossly infected and thus offer little chance for the survival of more suitable types of replacement.

The disadvantages of using this medium for skin replacements are that the donor site is almost always spoiled as a donor area for other types of graft; the donor and recipient areas are unsightly; and the result is functionally unsuitable because of the massive scar tissue between the pinch grafts.

The author heartily agrees with the statement of Gabarro, when he says: "Many reasons are given to explain why the pinch graft takes so easily. In my opinion, the main reason is that the grafts are so placed that enough room is left between them to allow of free discharge, and nothing intervenes between the graft and the recipient area." The use of the pinch graft has, therefore, resulted in applying emphasis to an important surgical principle. In infected or potentially infected wounds, adequate measures must be taken in the application of other forms of skin transplantation to assure free drainage for the successful take of the graft. This will be elaborated upon later.

Many varieties of pinch grafts have been described. They include the chessboard graft of Gabarro, Poth's strip grafts, cut to form "flagstones", the sieve grafts of Douglas, and postage-stamp grafts. A long glossary of names may be compiled to designate variants of the multiple small grafts. The one feature which differentiates these grafts from the Reverdin and Davis grafts is that a sheet of split-thickness skin is cut, either free hand or by mechanical means, thus assuring regeneration of the donor site. The graft is then cut into various shapes and sizes and placed upon the recipient bed. Many methods of maintaining contact between these small pieces of skin and the bed have been described. Among them are the coagulation contact method and the pliofilm-covered multiple grafts of Hardy and McNichol. Other variants of multiple small grafts may be mentioned, including Braun's method of burying small pieces of living skin in the depths of the granulating tissue in heavily infected areas, and the tunnel grafts described in 1912 by MacLennan and in 1917 by Esser. All these methods have limited usefulness in special cases; they are not methods of choice, but of necessity.

The scrape and injection method[1,10] of skin-grafting is mentioned here merely to condemn it as unsurgical in principle and unsatisfactory in results. In no case thus far reported has healing taken place before the lapse of many months of treatment, and the end result was unsatisfactory functionally and cosmetically. Infinitely more adequate methods are known, based upon sound surgical principles of preoperative care of the recipient area and resurfacing of the wound.

Credit for the full-thickness graft rightly belongs to Blair, John Staige Davis, Garlock, Dragstedt, and Conway. Filatoff in 1916 and Sir Harold Gillies in 1917 introduced the tubed-flap graft.

Padgett introduced the dermatome, which placed in the hands of surgeons an instrument that makes the cutting of a graft a matter of mechanical precision. To Blair, Brown, McDowell, and Padgett go the credit for the introduction and popularization of the split-thickness graft.

Recent literature is replete with references to new techniques in the use of free grafts. Some are based upon sound scientific principles and will endure; and others will disappear into oblivion.

THE SPLIT-THICKNESS GRAFT

The split-thickness graft has the greatest range of usefulness in the repair of skin loss of all methods of skin transplantation. Three types are to be distinguished: first, the thin split-thickness graft, or Ollier-Thiersch graft; second, the intermediate split-thickness graft of Blair; and third, the thick split-thickness graft. These differ from one another only in the amounts of epidermis and dermis which are taken. At one time it was believed that the Thiersch graft represented merely the epidermal elements of the skin; but all authorities agree that it is somewhat more substantial than that, and includes at least parts of the papillae of the skin. Its thickness is usually between 0.006 and 0.01 inch. The intermediate split-thickness graft of Blair varies from 0.012 to 0.016 inch. The thick split-thickness graft is from 0.02 to 0.024 inch; it may represent from two-thirds to four-fifths of all the skin elements present. The intermediate and split-thickness grafts have in a large measure displaced other forms of skin transplantation, except in special cases. They do not have the disadvantages of a Thiersch graft, which is inadequate functionally and cosmetically. The Thiersch graft, although useful and successful as a temporary coverage to obtain healing in moderately infected areas, is unsuitable for weight-bearing surfaces and areas exposed to trauma; and its property of contraction makes it unsuitable for use over joints or mobile surfaces. The full-thickness graft is also rapidly being replaced in large measure by the use of the thick split-thickness graft, except in cases of syndactylism or Dupuytren's contracture, and in small areas. A split-thickness graft of from 0.02 to 0.024 inch has almost all the advantages of a full-thickness graft, without the risk of loss. In the hands of the most expert operator, partial or total failure of full-thickness grafts occurs in 20 per cent. of cases in the aseptic wounds; in the granulating wounds the percentage of take is so small that it does not warrant the risk.

A split-thickness graft or any free graft will not "take" on exposed tendons or bare cortical bone without periosteum; but if the area is small—for instance, less than one centimeter—it may carry a lateral blood supply of its own to bridge small areas. The split-thickness graft takes well on fat, muscle, granulation tissue, and even on scar tissue. Furthermore, a split-thickness graft causes no concern about coverage of the donor area, as rapid regeneration in this area from sweat glands and hair-follicle elements is assured. Brown and McDowell[4] have referred to this as "dedifferentiation" of the deep glands of the derma into squamous epithelium, and state that the squamous epithelium covers the surface in from six to eight days.

The thickness of whole skin varies greatly according to age, sex, race, complexion, various degrees of nutrition, and different areas of the body. The character of the skin varies also in different portions of the body. In children, the skin rarely exceeds 0.016 inch in thickness. In adult males, the skin is thicker than in females; in fair-complexioned people it is thinner than in dark-skinned individuals. The skin from the chest, abdomen, inner aspect of the upper arm, or inner thigh is thinner than that on the back, outer thigh, or buttocks.

On the back the epithelium is relatively thin, but the derma is so thick that a full-thickness graft from this area cannot be relied upon to survive. This region, however, is useful as a donor area for repeated grafts. Brown and McDowell[3] report taking five crops of split-thickness skin from this area; in one instance, only nineteen days elapsed between the taking of two successive grafts. The skin on the palms and on the soles of the feet is the antithesis of that on their dorsal aspects; the epithelium is thick, the derma is thin, and hair follicles are not present.

Homografts take almost universally, even without regard to blood groups. Brown and McDowell report their use in twenty-six patients who were grouped by the M and N classification. Although these homografts may be life-saving and are frequently used in children with extensive burns, they begin to disappear in three weeks by a melting-away

process without pus formation, and are completely absorbed in from ten to eleven weeks. It appears that the proteins of homografts are antigenic and that the host requires about three weeks to build up a maximum allergic response, as evidenced by the fact that application of a second homograft from the same donor fails completely. As an emergency measure, it stops pain; there is improvement of the patient's general condition; and the graft appears to stimulate the wound to epithelialization. Brown, in 1937, reported one instance of successful homografting in identical twins.

Skin preserved by refrigeration usually fails to take, although isolated cases of success have been reported with skin preserved up to two weeks. In the author's opinion, it is useless to tempt fate with so uncertain a procedure.

Split-thickness grafts can be used in the following situations: (1) in clean granulating surfaces; (2) over the yellow base left by excision of granulation tissue; (3) in extensive burns, crushing injuries, or avulsions; and in infections with loss of tissue, as soon as the granulating bed is clean; (4) over fresh raw surfaces, if subcutaneous tissues are still present in the floor of the wound; and (5) as an intermediate step before the application of a full-thickness graft in obliterating osteomyelitic cavities.

Obviously the thicker the split-thickness graft, the better the coverage and the less the shrinkage. A thin graft or one of intermediate thickness, on a fresh raw surface or on a movable base, may contract as much as 60 per cent. When laid on a freshly denuded scar base, on periosteum, or in an area surrounded by tense skin, the shrinkage is less. Other factors that the surgeon will have to weigh are the available donor sites and the presence of infection. Should any question arise about the cleanliness of the recipient area, the surgeon would do well to err on the side of conservatism and choose a graft of lesser thickness, rather than risk the loss of a thick split-thickness graft.

The Mechanism of Take

The graft, securely sewed into the recipient area with adequate hemostasis and firm, even pressure, heals in a manner quite comparable to the healing of a bone graft. In about five hours the graft is firmly attached to the base by the formation of fibrin, and leukocytes and fibroblasts begin their invasion of the clot. According to Goldmann, for the first twenty-four to forty-eight hours the viability of the graft hangs in the balance, depending as it does upon the plasma and the lymph for its nourishment. In about eighteen hours endothelial buds, arising from the proliferation of the endothelium of the host blood vessels, begin to invade the graft. Padgett is of the opinion that endothelial buds connect with the endothelial spaces of the graft. He believes that the failure to connect with the endothelial spaces of the graft causes local degenerative changes to take place. This is the reason for sewing a graft into place under normal tension, so as to establish and maintain the patency of these endothelial spaces. Reichert demonstrated that the regeneration of small arteries across clean operative wounds occurs by the end of the second day, that veins and lymphatics become anastomosed by the end of the fourth day, and that the process is physiologically complete by the eighth day after operation. Davis and Traut believe that a graft is nourished, first, by the plasmatic circulation of Goldmann for the first twenty-four to forty-eight hours; second, by direct anastomosis between the vessels of the graft and the host; third, by the growth of capillaries of the grafted area into and along the degenerated vessels of the graft; and fourth, by the capillary upgrowth from the grafted area as it penetrates the connective tissue.

It is obvious, therefore, that the thicker the graft, the greater is the risk of failure. That is the principle which demands the removal of the fat layer from the free full-thickness graft; because of its greater thickness, death occurs before vascularization is complete.

In four or five days, organic union between the graft and the host is fairly firm. On the eighth day the blood supply is nearly complete. By the tenth day the two are united

by fibroblasts which, having invaded the clot by using the fibrin as a scaffold, connect the fibrous tissue of the two sites. The infiltration of fibroblasts into the graft is responsible for its contraction. Hand in hand with the proliferative changes—that is, the invasion of the graft by endothelial buds and fibroblasts—degenerative changes occur. The process can be likened to creeping substitution in the repair of bone. The exact mechanism is unknown. In the case of the elastic fibers in the graft, Padgett concluded that the elastic fibers degenerated and reappeared, "but not in the orderly manner which is characteristic of normal skin. Although the ultimate disorderly arrangement of the elastic fibers may have something to do with the tendency toward a glistening appearance of a skin graft, it is more likely that it is the replaced fibrous tissue which tends to obliterate the normal surface corrugations in the epithelium of the graft."

Exfoliation of the most superficial layers of the graft not infrequently occurs, and this varies in degree in direct proportion to the speed of vascularization of the graft.

Microscopic sections of the graft during this stage of adaptation not infrequently reveal collections of leukocytes at various levels. These, of course, are increasingly numerous as the grafts become thicker.

After the lapse of two or three months, the cellular infiltration disappears. The fibroblasts become mature compressed cells of fibrous tissue, and lose their plump, spindle-shaped appearance. A layer of fat of variable thickness is now found to line the deep surface of the graft, permitting it to move freely over the underlying tissue. The thickness of this adipose layer varies with the thickness of the graft, being more abundant in the full-thickness graft than in the split-thickness variety.

Full normal sensation usually develops in free skin grafts; it is influenced by the amount of deep scar tissue that is left behind, and depends upon the presence of sensory nerves in the area and on the thickness of the graft. The sensations of pain, temperature, and touch may develop as early as five weeks or as late as several months.

Because the skin on the palm or the sole is highly specialized, with a thick epithelial layer and a relatively thin dermal layer, metaplasia of free grafts—and, for that matter, of flaps—does not take place. Therefore, grafts in these areas must always be protected.

The Use of the Padgett Dermatome

The Blair-Brown knife-and-suction-box technique in the hands of the expert is excellent. With the Marcks attachment, its use has become more simplified; but with the invention of the Padgett-Hood dermatome, broader horizons have been opened up for the early replacement of lost skin. The means to select a graft of predetermined thickness has been placed in the hands of an operator. The dermatome has the following advantages: (1) Its mastery is comparatively simple and can be acquired by the average surgeon; (2) grafts of uniform thickness (four by eight inches) are obtainable; (3) it increases the number of available donor sites,—for example, the chest and the area over the ribs.

With the mechanical means at hand to obtain adequate split-thickness grafts, it is a matter of little experience to obtain surface covering. There are, however, certain important points to be observed in securing a graft. Every step must be meticulously carried out.

The drum, the brush, and the donor site must be absolutely dry; no trace of moisture must be present. It is well to go over the drum and skin with ether to assure the dryness of these areas.

The quality of the blade and its sharpness must be assured; it is placed in the instrument with the bevel away from the drum, and held in place by the clamp. It has been the author's practice not to use the same blade more than three times without having it resharpened. Ideally, of course, the blade should be sharpened after every use. Great care should be taken to avoid nicking the blade against the instruments and against the drum. It should be sterilized by cold sterilization.

The drum is now set at the predetermined thickness and placed on its rack, pending the preparation of the donor site, which will be described later.

The operator, having assured himself that the drum, the blade, and the donor site are clean and dry, is ready to apply the rubber cement. The cement is not poured until it is ready for use; if poured too soon, its volatile elements evaporate and the viscosity increases. The optimum viscosity of the cement is also a matter of importance. If too thick, ether should be added until the proper consistency is obtained.

In applying the adhesive, the drum is held in the left hand, with the back of the blade and the carriage resting on the operator's wrist. The brush should have fine bristles, about one and one-half inch to two inches wide. The cement is applied to the drum in a thin layer, with sweeping strokes. There must be no back-and-forth brushing; a thick layer of cement will dry unevenly and may invite failure. The edge of the drum should be adequately covered with glue, as this is the edge at which the blade engages the skin. Good adhesion between the skin and drum at this point is of utmost importance.

After the application of the cement to the drum, and while the drum is still being held in the left hand, the donor site is painted with the adhesive. The same precaution of smooth, even application of the cement is observed. Drying can be hastened by gently fanning with a folded sterile towel. The length of time required to dry the cement varies with the cement itself, its viscosity, the thickness of the application, the temperature of the operating room, and the humidity. Therefore, the time element cannot be estimated, but rather the dryness can be determined by the loss of the glistening sheen of the applied cement.

The edge of the drum is placed at the top of the donor site and pressed down firmly for a few seconds so that the entire edge of the drum is engaged by the skin. Then, by gently rolling the drum slowly, the blade is brought into action and, by a sawing motion, the desired amount of skin is obtained. This may be the size of the entire drum, or any portion of it. When the desired amount has been obtained, the drum is pulled at right angles to the skin surface and, with the blade still operating, the graft is severed from its attachment.

Failure of any steps necessary for the successful application and adherence of the cement to the drum and skin calls for immediate cessation of the procedure, which must be started again from the beginning. This means that every vestige of cement must be removed from the drum and the skin. Should blood or moisture be present on the drum or the donor site, it is scrupulously removed and the area is dried by sponging with ether.

The graft is now removed from the drum by grasping the edge with mosquito hemostats placed on the four corners of the graft. The small areas grasped and crushed by the hemostats are cut away before the graft is sewed into place. If the same precautions are used that one would exercise in the handling of adhesive tape, the graft will not become stuck to itself.

The graft is not placed in saline before use, but is merely placed in the folds of a damp towel, or the cut surface is folded on itself. If the graft were allowed to soak in a basin of saline, the serum in the endothelial spaces would be washed out, small amounts of natural adhesive agents present would be removed, and the take of the graft might be jeopardized.

It may appear from this discussion that the technique of obtaining the split-thickness graft by means of a Padgett dermatome is difficult. This is not so. With a reasonable degree of attention to the details involved and with average skill, the graft is obtained easily.

THE USE OF THE SPLIT-THICKNESS GRAFT

Three types of wounds must be recognized for the successful use of a split-thickness graft: (1) the wound accidentally incurred within a period of a few hours; (2) the wound created surgically following the excision of a scar; and (3) the granulating wound.

The granulating wound may be the result of a burn, an infection, or an avulsion of skin. The management of each of these three types must be different to assure the greatest number of successes.

1. *The Treatment of the Early Traumatic Wound*

The accidentally incurred wound, if seen within six hours, can be treated in the same manner as the surgically excised scar. It is true that the wound is contaminated, but infection is not present. Organisms exist in small numbers, but they have had little opportunity to multiply or to penetrate deeply into the tissue. They can be removed by mechanical cleansing and by débridement. If important structures—such as bones, major blood vessels, nerves, or tendons—are exposed in the wound, it is well to undermine the edges widely to afford primary coverage for them. If insufficient skin is present to allow for such closure, a relaxing incision—well removed from the skin edges and over unimportant structures—is made and the skin is slid over. The defect produced by the relaxing incision is then treated by the insertion of a split-thickness graft. If the defect is of such great size that these methods are not applicable, a broad-based flap can be raised and sutured into place immediately, or a pocket graft may have to be considered. These procedures are beyond the scope of this paper. However, if the wound is more than six hours old, it must be considered as infected and treated by the methods described later.

It should be emphasized that a very early accidental wound or a wound due to the excision of a cicatrix can be treated as a clean wound, but the granulating wound must always be treated as an infected one. The principles of treatment differ radically one from the other.

2. *The Treatment of the Aseptic Wound*

By an aseptic wound is meant one that has been created by the excision of a cicatrix.

The donor and recipient sites are prepared twenty-four hours in advance of the operation by shaving, washing with Castile soap and water, followed by washing with ether and alcohol, and wrapping in sterile towels.

The patient is brought to the operating theater, where the final preparation of both sites is undertaken. After scrubbing the hands in the prescribed manner for ten minutes, the surgeon or his assistant dons a pair of rubber gloves and proceeds with the preparation of the skin. This is done by washing the areas eight or ten minutes, using soap, water, and gauze. The soap is removed by pouring copious amounts of water over the area. Germicidal solutions are not used, since the author believes that they have no advantage over the soap and water, and are even harmful to the graft. The surgeon now discards his gloves and, after using the operating-room solutions again, puts on his operating gown and new gloves. The donor area is draped in the usual manner, and in such a fashion that ample freedom for the operation of the dermatome is available.

A solution of 0.5 per cent. procaine, containing six to eight drops of adrenalin to the ounce, is used to infiltrate the scar bed. The procaine is not used for its anaesthetic value, but merely as

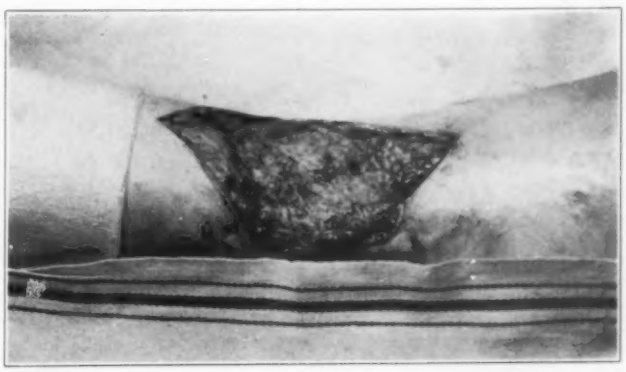

FIG. 1

Contracture of the popliteal space after a burn; shows the aseptic wound. Note (1) complete excision to normal unscarred tissue; (2) complete hemostasis; and (3) staggered line of excision.

FIG. 2

Graft has been sewed into place under normal tissue tension. Stay sutures have been used in recipient area, with "pie-crusting" of graft.

FIG. 3

Xeroform gauze (44 by 40 mesh) has been impregnated with 3 per cent. solution of bismuth tribromphenate. The gauze, two layers thick, has been laid smoothly, without wrinkles.

FIG. 4

Dressing is being tied into place with stay sutures to exert firm, even pressure and to prevent displacement of dressing. If this patient had had a late traumatic wound or a granulating wound, catheters would be placed at this level.

FIG. 5

Shows voluminous dressing of fluffed, washed gauze sponges. Dressing surrounds entire limb; over these fluffed sponges are laid large laparotomy pads.

FIG. 6

Shows final dressing, with bias-cut stockinette bandage, extending from ankle to above grafted area.

a vehicle to convey the adrenalin. The adrenalin assures a dry bed until the graft has been sewed into place and the compression dressing has been applied.

If the area will permit, a tourniquet is used and the adrenalin solution may then be dispensed with. The pneumatic tourniquet is preferred, particularly in the upper extremities. This tourniquet or a blood pressure cuff is inflated to 260 millimeters of mercury. Because skin-grafting is a long procedure, it is advisable to release the constrictor for a few minutes after the lapse of forty-five minutes.

Excision of the scarred area is now undertaken. This must be complete, and the underlying normal tissue must be exposed. The area to be excised is outlined with gentian violet, 5 per cent. brilliant green in alcohol, or Bonney's blue solution. The suture line, which contracts in its long axis, is staggered by the making of gores in the excising incision. In this way is prevented the formation of bands, which frequently give rise to imperfect results.

Perfect hemostasis is absolutely essential for success. This is obtained, first, by the adrenalin solution or the tourniquet. A blood vessel that requires tying should be ligated with the finest silk obtainable, and the knot cut short. Small vessels often can be treated by crushing and torsion. The use of the coagulation current is not favored, as it leaves a small mass of necrotic tissue, which may vitiate the result of the graft. The use of an absorbable suture is condemned; it gives rise to an inflammatory exudate for its absorption, and therefore is prejudicial to the success of the graft. Hot saline sponges applied locally are useful to control the oozing from capillaries. Many surgeons are thoughtless in the use of hot saline sponges; a sponge which is too hot for the surgeon's gloved hand is

obviously damaging to the tissue. The temperature of hot sponges should not exceed 120 or 130 degrees Fahrenheit.

Brown and McDowell[4] state that sulfanilamide may be dusted sparingly over the bed. The author agrees with their observation that an excess amount of the powder interferes with the graft, and prefers to rely upon the surgical principles of moisture and adequate drainage.

The graft is now sewed into place. It should be so planned that the maximum area is covered without piecing. If the area is so large that it requires more than one drum of skin, the sections may be pieced before being sutured to the defect, as was recommended by McPheeters and Nelson,—the so-called "blanket graft". The graft is handled with great gentleness, with skin or dural hooks; the use of tissue forceps is not permissible. The graft is sewed into place with interrupted sutures of Size 6–0 silk. The advantages are twofold: First, better cosmetic results are obtained; and second, the silk is so fine that it will not withstand a great deal of tension and will tear long before the tissue is strangulated by too tight a suture. Such a fine suture material may try the patience of the novice, but it pays handsome dividends to those who learn to use it successfully. As stated previously, the normal skin tension of the graft is important to the success of the operation. After anchoring the graft at one point, the edge is picked up with a dural hook and is stretched to the point where its elasticity almost disappears. At that point it is fixed to the incised edge of the recipient area.

Small incisions are made into the graft with a No. 11 Bard-Parker blade, to allow for the egress of any collections of blood or serum. "Stay" sutures are now placed around the periphery of the wound in the recipient area; these are left long (Fig. 2). One or two thicknesses of 3 per cent. xeroform gauze, on fine 44 by 40 mesh, are laid smoothly, without wrinkles, over the graft, with slight overlapping of the sutured edge (Fig. 3). Over this are placed ten or twelve layers of ordinary gauze, which are tied snugly into place by means of the stay sutures (Fig. 4). Tying the dressing into the wound prevents shifting of the dressing and tenting, and helps to apply firm pressure so that serum cannot collect beneath the graft. The author agrees with Brown and McDowell[4] that vaseline gauze tends to cause maceration of the tissue; whereas any powder added to it, such as sulfanilamide, xeroform, scarlet red, or boracic acid, prevents maceration. After the dressing has been tied into place, voluminous fluffed gauze, mechanics' waste, or sea sponges are placed around the circumference of the limb, and all are held in place by a stockinette bias-cut bandage (Figs. 5 and 6). The voluminous dressing frequently affords adequate immobilization; if not, it may be supplemented with immobilizing apparatus.

Important as are the cutting of the graft, the preparation of the recipient area, the absence of infection, and complete hemostasis to a successful take, the application of the dressing is of no less importance. The preparation of the recipient area, the cutting of the graft, or the sewing of the graft into place may be delegated to the assistant, but it is a surgeon's responsibility to apply the dressing.

The recent literature has many references to new methods of application of split-thickness grafts. It might be well to examine these methods in the light of surgical principles.

In 1943, Sano introduced the coagulum contact method of affixing the graft to the recipient bed. This followed the observation that growth of tissue culture was obtained uniformly and successfully when cells were supplied with a suitable surface for growth through the use of coagulated plasma, and when adequate nutrition—through the medium of embryonic tissue extract in a buffered salt solution (Tyrode's solution)—was present. The most satisfactory results were obtained by the use of homologous plasma and tissue extract.

Later that year Sano, Holland, and Babcock described the method of making the two solutions for coagulum contacts. One milligram of heparin was added to five cubic centi-

meters of blood and centrifuged. The blood separated into three layers: the supernatant plasma, a layer of leukocytic film (the so-called "buffy coat"), and the red corpuscular layer. The plasma is poured off and is called Solution A. The buffy coat is removed with a platinum loop, and placed in a sterile test tube containing three cubic centimeters of Tyrode's solution; and a cellular extract (Solution B) is made by shaking the solution vigorously with sterile glass beads. The recipient area is flooded with Solution A and the graft is painted with Solution B; when the two surfaces are brought together, coagulum fixation occurs. It has been advocated for the Reverdin, Davis, and Thiersch types of grafts, for split-thickness dermatome grafts and full-thickness grafts, on granulating or fresh wounds. The proponents claim its superiority chiefly on the basis that the adhesion is so perfect that suture and pressure dressings are unnecessary.

Cohn and his associates, having isolated the thrombin and the fibrinogen fractions of plasma, have simplified the method considerably. The thrombin in aqueous solution is sprayed with an atomizer and is applied to the graft. The fibrinogen is applied to the recipient surfaces.

The writer has had insufficient experience with the procedure and therefore reports the results of other observers. Young reports as follows: In twenty-six cases of split-thickness grafting, there was 100 per cent. take in twelve cases of primary grafts. In four cases of fresh traumatic contaminated wounds, there were 48 per cent. takes. In ten granulating wounds, a 59 per cent. average take was estimated; in two of these cases the graft was totally lost. Young concludes that "it is our definite impression that the loss of grafts is considerably greater on infected wounds when applied by this method than when compression dressings are used. This applies to contaminated fresh wounds as well as to granulating beds. It is probable that infection is sealed under the graft, drainage is poor and the result is a purulent collection under the graft which prevents vascularization."

Jenney states that he, J. Eastman Sheehan, and Lawrence Gatewood found that pressure dressings and immobilization are essential for best results with the Sano technique. This ensures perfect apposition of the graft to the recipient area and prevents air pockets, oozing, and blood accumulations.

It would thus appear that the coagulum contact method does not fufilll the surgical principles of maintenance of normal tissue tension and firm, equalized pressure; and it ignores the concept that all granulating wounds must be considered infected, and therefore must be treated by moist dressings. Davis and Traut, in 1925, and Davis in 1927, emphasized the need for maintenance of normal tissue tension and stated: "We also found that the contraction of the elastic fibers in the skin occluded the vessels, and for that reason when securing the graft in position, we apply tension equal to that of the normal skin to overcome this tendency".

If one ignores the absence of tissue tension—and it is a factor that cannot be lightly disposed of—it is obvious that in the freshly created surgical wound the graft may take well; but in the presence of potentially infected wounds—that is, granulating surfaces and contaminated traumatic wounds—proteolytic enzymes are liberated from degenerating white cells, and digestion of the fibrin takes place.

Koch states that "only in unusual instances are we willing to lay a flap, with an assured blood supply through its pedicle, over a granulating surface, so concerned are we over the destructive effect of even a few bacteria on the vulnerable subcutaneous tissue which forms the undersurface of the flap".

The author, therefore, is compelled to conclude that the Sano technique has a very limited application and does not fulfill the basic requirements of sound surgical principle in so far as split-thickness grafts in unclean wounds are concerned. If the technique is extended to include such factors as the maintenance of normal tissue tension and firm, equalized pressure, and the application of moist dressings in the potentially infected wound, it offers very little advantage over the conventional method of graft suture.

A great deal has been written about the desirability of cutting a graft according to the exact pattern of the defect. To the writer, this objective is unsound and worthless. The donor site in a split-thickness graft has present all the elements necessary for regeneration. A donor site, from which a graft has been removed, heals as well and as rapidly if ten square inches or the maximum of thirty-two square inches have been removed, provided adequate after-care is given. In removing skin for a graft, it is well to take somewhat more than is required, but to cut exact patterns is wasteful of time and effort and serves no useful purpose.

Other writers have advocated the cementing of nylon, plioform film, cellophane, bobinette, or other material to the drum, and then taking the graft in the usual manner by painting this material and the skin. This is so that normal tissue tension may be maintained by the transfer of the skin and the material which is adherent to it. Another alleged advantage is that it saves time and does not require suturing to the bed. In the author's opinion, these additions to technique are not only unnecessary, if one adheres to the sound surgical principles of the management of split-thickness grafts, but are not time-saving, because the time necessary for the application of the material to the drum could well be used for suturing the graft into place.

3. *The Treatment of the Granulating Wound*

The optimum time for transplantation of skin to a granulating bed is of first consideration. A great deal has been written about the bacterial content of the granulating wounds. Lange has described the intravenous use of ten cubic centimeters of 5 per cent. fluorescein buffered with 5 per cent. sodium bicarbonate; the area is then inspected in the dark room under the influence of a mercury vapor lamp, screened to emit 3,600 Angström units. An adequate blood supply to the part is determined by the appearance of an intense golden-green color in from fifteen to twenty seconds; an inadequate blood supply is evidenced by a dark purple or slightly bluish-green color. Sheehan has advocated the determination of the oxygen and sulfur content of the skin as an index for grafting. These studies are of academic interest only, and can be dispensed with. The most useful criterion is the appearance of the ulcer itself. It should be free from grayish slough or gross pus; the exudate should be thin and scanty; the granulations should be firm, pink or red, should present a cobblestone appearance, and should be flush with the skin surface. They should not be pale, anaemic, exuberant, or oedematous. Healthy granulation tissue bleeds easily on irritation and is relatively painless. Epithelial ingrowth from the edge, which presents a beveled appearance, is observed in the healthy ulcer. There should be no surrounding redness, inflammation, or cellulitis, or heaping up of epithelial debris.

To assure an adequate granulating surface for a successful split-thickness graft, one must be guided by general constitutional and local factors.

General Constitutional Factors: Grafts do not take well in patients with chronic debility, or in the presence of anaemia, hypoproteinaemia, dehydration, avitaminosis, oedema, or disturbance of the electrolytic balance. Furuncles, either local or remote, are inimical to grafts. In children, grafts take better than in the aged, but the difference is not marked. When the hemoglobin is reduced to below 65 per cent., the percentage of take decreases from one-third to one-half. It is obvious that general treatment must be directed toward the correction of such abnormalities.

Local Factors:

Granulation tissue is infected tissue and, in preparing such an area for the application of the graft, we must rely upon sound surgical principles of cleanliness, rest, elevation, free drainage, and moist dressings which afford moderate compression. Ointments and dry gauze are contrary to sound surgical judgment. They favor retention of secretions and prevent adequate drainage. The author believes that local application of the sul-

fonamides, gramicidin, or penicillin is not necessary, but may be used as an adjunct. Local trauma to the granulation tissue must be sedulously avoided. Fine mesh gauze (44 by 40) is laid over the raw surface. This prevents the granulations from growing into the interstices of the gauze and being pulled off with each change of the dressing. The solution used for moist dressings is in itself of little moment. It can be normal salt solution, boracic acid, or magnesium sulfate. The principal consideration is not the specific property of the solution, but the moisture supplied, which promotes the flow of lymph and provides drainage.

Pyocyaneus infection is particularly hazardous to the successful take of a graft. Although Blair and Brown recommend the frequent painting of the area with gentian violet or methylene blue, the use of proprietary mercurials, and copious use of soap and water, and although they look with disfavor upon the use of hydrogen peroxide and acetic acid, it has been the author's experience that the use of acetic acid in strengths of from 0.5 to 2 per cent., before and after operation, has met with uniform success.

Objections may be raised that continuous moist compresses result in maceration of the tissues. It has been the author's experience that, when moist dressings are used in conjunction with a voluminous dressing, moderate pressure, and elevation, maceration does not occur, because the circulation is well supported and the compression dressing prevents water-logging of the tissues. It is also noteworthy that pale, flabby, oedematous granulation tissue under the influence of elevation, moisture, and pressure rapidly becomes firm, pink, and healthy in appearance.

The Management of the Split-Thickness Graft in Granulating Wounds:

It is advantageous to have a competent assistant in planning extensive skin-grafting. If the recipient area is a granulating wound and hence must be considered infected and unclean, the operator, if he works alone, works from the clean field to the unclean. He takes his graft first and then prepares the recipient bed. With a competent assistant, however, the taking of the graft and the preparation of the recipient area can be done simultaneously by the operator and his assistant, working independently in the different areas. In this way the operating time can be shortened measurably.

Assuming that the granulating surface has fulfilled all the conditions necessary before skin transplantation is undertaken, the epithelial edge is circumcised by sharp dissection. This is important because, without the removal of this tissue, there is an irregular, unsightly area of union between the graft and the host.

The question may be raised as to the management of the granulating wound at the operating table. Authorities differ as to whether one should remove the base or leave it in place. It has been the author's practice to leave the granulation tissue, if it is of recent origin and short duration. If the ulcer is old and calloused, it is advisable to remove the granulation tissue by sharp dissection—never by scraping—to the smooth yellow base, which has a satisfactory blood supply. At times it is possible to excise the ulcer *in toto*, and place the graft on the normal underlying tissue. In old cases with contracture, one may crosshatch the base and correct the contracture before the application of the graft.

The graft can now be sewed into place. Attention should be paid to hemostasis, gentleness of handling, sewing the graft into place under normal tissue tension, placing of basting sutures if there is any tendency to tenting, and "pie-crusting" the graft with multiple small incisions.

Up to this point, the techniques of surfacing the aseptic, fresh traumatic wound and the granulating wound parallel one another rather closely; but from this point on the techniques diverge. In the aseptic or recent traumatic wound the dressings may be dry, but in the granulating wound—because it is potentially infected—the dressings must be wet. This is a fundamental concept, with which there can be no compromise if uniformly successful results are to be expected.

Stay sutures of medium silk are placed one-half inch from the graft, around the

periphery. Usually two or three are required on each side, external to the recipient area. The graft and the surrounding tissue are sponged off with hydrogen peroxide. The purpose of this is to enable the operator, on subsequent visits to the patient, to detect, by the odor of the dressing, the presence of suppuration or pyocyaneus infection without the mingled odor of dry or stale blood. Bandage gauze of the finest quality, 44 by 40 mesh, eight to ten layers thick, is now cut to pattern so as to overlap the margin of the graft. This is wrung out in normal salt solution and laid smoothly, without wrinkles, upon the graft. This may appear to be an unimportant step; yet, at the point at which wrinkles occur, failure of the graft to take may result. Moistened gauze dressings, laid smoothly, are placed over the bandage gauze, and the whole is tied into place with the stay sutures. As pointed out previously, this is of material help in exerting firm, even pressure over the graft, and prevents the dressings from sliding and becoming misplaced. Two or three No. 18 French catheters, with additional holes cut into their distal ends, are now placed over the dressing in a radial fashion. Over this and surrounding the entire limb are placed moistened mechanics' waste, fluffed, washed gauze sponges, or sea sponges, and the whole is covered with a large laparotomy pad. It is important that voluminous resilient dressings surround the entire limb, and are not placed merely over the grafted area, in order to exert uniform pressure over the whole limb. Holding all these dressings in place is a stockinette bandage, which is cut on the bias, six to eight inches wide, from tubular stockinette. The advantage of this over the conventional elastic or crepe bandage is that it can be cut in far greater length than the usual five and one-half yards. This bias bandage is applied snugly from the most distal part of the limb to well beyond the grafted area. In this manner, it exerts even pressure over the grafted area and supports the circulation above and below the graft. One need have very little concern about the tension of this bandage if a truly voluminous dressing has been applied, for the writer has never seen embarrassment of the distal circulation.

The question of immobilization is the next concern. If the dressing has been voluminous, very little additional immobilization is necessary. If in the opinion of a surgeon, however, immobility is incomplete, basswood, a pillow, or a Thomas splint may be used to advantage. A plaster-of-Paris cast is definitely contra-indicated, as it softens from contact with the moist dressing and interferes with the evaporation of the surface moisture. In addition, it is heavy and cumbersome.

The after-care of the grafted area is of utmost importance to the success or failure of the operation. Without interruption, the dressings must be moistened by means of the catheters every four hours, day and night, with boric-acid solution or normal salt solution. This is important, because it makes up for the loss of moisture from surface evaporation. If the area was the seat of pyocyaneus infection, it has been the author's custom to omit one or two injections of boric-acid solution or normal salt solution and to use instead a solution of acetic acid in strengths of from 0.5 to 2 per cent. This has been very effective in controlling the pyocyaneus.

The purpose of using moist dressings in granulating wounds is that the moist solution, in contact with the grafted area, promotes the flow of lymph to the bed, and so offers nourishment to the graft. It prevents the formation of crusts, which would block drainage. Evaporation of moisture from the surface of the dressing causes good drainage, because, as fluid is delivered to the bottom layers of the dressing, by capillary action the fluid rises to the surface. Evaporation on the surface augments the effectiveness of the drainage. Maceration of the tissue does not occur.

Important as it is to supply a sufficient amount of solution to the dressing—and this, of course, varies with its size—it is just as important not to supply too much. The dressing must not be so wet as to lie in a pool of solution. Neglect of this precaution is most dangerous to the graft, for the dressing lying in a pool of liquid acts as a wick, and unsterile solution is brought to the grafted area by the same process of capillary action.

When the correct amount of fluid is being supplied, the outer surface of the dressing should feel only slightly damp.

Dressing of the Donor Site:

The skin of the donor site regenerates by virtue of the fact that the epithelial elements of the skin—that is, the sweat glands and hair follicles—are left behind.

In order to avoid pain and discomfort, and to ensure proper healing of this area, extreme care must be taken in the dressing. Although numerous methods have been advocated, such as tanning with escharotics, or the application of silver foil, it has been the author's experience that the most suitable dressing is the one in which firm pressure is secured against motion.

After the graft has been obtained, the donor site is temporarily covered with a towel, wrung out in normal salt solution. The towel is in intimate contact with the donor site, and is undisturbed until all procedures in the recipient area are completed and the dressing has been done. After this, strips of 3 per cent. xeroform gauze are laid smoothly upon a large abdominal pad. While the assistant removes the towel over the donor site with alacrity, the surgeon without loss of time places the xeroform-covered abdominal pad over the site. Firm pressure by the assistant is maintained until additional soft pads are placed about the circumference of the limb, and the whole is bandaged snugly with a bias-cut stockinette bandage.

This may appear to be a surgeon's fetish, but sound principles are involved. The moist towel over the donor site arrests the punctate bleeding from this area. Its removal, because of its adherence, causes fresh bleeding which, if allowed to be present under the dressing, acts as a nidus for infection. It is, therefore, advisable to effect the transfer of a xeroform-covered pad for the moist towel with a minimum loss of time, and to maintain even pressure throughout the healing period with the bias-cut bandage.

If the patient is afebrile and daily inspection of the dressing reveals no suppuration, the dressing is left undisturbed for fourteen days; at this time it is removed, and the area will be found to be completely epithelialized. The dressing is always firmly adherent to the epithelialized donor site. Care should be exercised in removing the dressing not to strip off the delicate epithelium. Soaking with peroxide or normal salt solution is unnecessary, but gentleness is imperative. The use of a hemostat, to depress the skin gently as the dressing is removed, is of inestimable assistance. No further dressing is necessary. A protective emollient, such as 2 per cent. boric ointment, is sufficient to keep the skin soft.

At the end of two weeks the donor site is of a bluish color. This pales out in several months and leaves an area slightly lighter in color than the surrounding normal skin.

Postoperative Care:

Routine postoperative surgical care is supplemented with special attention to the graft. The limb is elevated; a Thomas splint or a pillow splint is very useful for this purpose. Dependency of the part is prohibited; under no circumstances is the use of crutches permitted, in the case of the lower extremity, until healing has been completed. Dependency may produce stasis in spite of the pressure dressing, and this is detrimental to the graft.

Two things are relied upon to determine the state of the grafted area without its actual exposure. These are the surgeon's sense of smell and the patient's temperature. The surgeon should sniff of the dressings at each visit, not casually or disdainfully, but by lifting a few turns of the stockinette bandage with his fingers and bringing his nose into close proximity to the dressing. This is done at several points, particularly around the edge.

The other indicator of the status of the graft is the patient's temperature. A slight elevation of temperature for from twenty-four to forty-eight hours is expected. Thereafter

the patient should be afebrile. The odor of suppuration or of pyocyaneus infection, or a persistent elevation of temperature should call for immediate inspection of the graft.

The donor site should not be overlooked. It, too, must be inspected daily and sniffed, because occasionally that area may be the seat of trouble. This is particularly true if the patient complains of a great deal of pain. It is not uncommon, however, to have patients complain of slight discomfort from the close adherence of the dressing to the donor area. Should infection occur in this region, the compression dressing is removed; and warm, moist dressings, such as would be used for any infection, are substituted.

There appears to be considerable confusion about the time of changing the initial dressing. Dogmatically, from ten to fourteen days has been set as the most propitious time for changing the dressing. Nothing could be more erroneous. There is no adequate reason why the graft should not be inspected at an earlier date. In fact, there are definite advantages to inspecting the graft much earlier. If a small clot, or a collection of serum or blood is present, that area may be saved by timely incision for evacuation of such fluid. Sometimes a suture may have been placed too tightly and may be causing strangulation of the tissues, and its early removal may prevent loss of that part. Occasionally mild infection may be present. Severe infection is beyond the hope of rescue; but, in the case of mild infection, an incision for the establishment of drainage and the immediate institution of moist compression dressings may save a large part of the graft. At times, small areas of dry gangrene of the graft are present. These can be recognized by their circumscribed, dry, brownish character; and, if small, they are of no great moment. The area is lost; but, as it is seldom larger than a five-cent piece, it becomes epithelialized from the remainder of the graft and there is no great difference in the end results. Should an area be definitely beyond the hope of saving, there should be no hesitation in excising it. The procedure is painless and can be performed at the bedside.

If the wound was an early traumatic or an aseptic surgical wound, the graft is inspected on the sixth or seventh day. If it was a granulating wound, the graft is inspected on the third or fourth day. If the patient is febrile, the graft is inspected at an earlier date.

Upon inspection of the graft in the first week, it may present a mottled appearance. Some areas, or the entire graft, may appear cyanotic. This is not to be interpreted as death of the graft, but rather as incomplete vascularization and diffusion of blood pigments. In such cases, it is well to continue with moist dressings until all such discoloration disappears.

Should the graft be dry, pink, and adherent to the base, one may apply a layer of gauze (44 by 40 mesh), without wrinkles, impregnated with 3 per cent. xeroform. Over this is placed a voluminous dry pressure dressing. This dressing is changed every three or four days for about three weeks. At the end of this period all dressings are discontinued, and 2 per cent. boric ointment is applied to keep the graft and the surrounding skin soft.

If there is any question about the status of the graft during the immediate postoperative period, one should at once revert to wet, voluminous pressure dressings.

Sutures are usually removed in two stages: Alternate sutures, or sutures that appear to be causing embarrassment to the circulation of the graft, are removed at the first dressing; the remainder at the end of ten days. At the first dressing of the graft, it is advantageous to cut the stay sutures in such a manner that they may be used again to tie the new dressing into place.

CONCLUSIONS

1. The split-thickness graft offers a wide range of usefulness, and, with average skill and a reasonable amount of diligence to the details involved, it is easily obtained by the average surgeon with the Padgett-Hood dermatome.

2. Three types of wounds requiring split-thickness grafts must be recognized: the early traumatic wounds, the aseptic wounds caused by the excision of a scar, and the

granulating wound, which requires different management. Early traumatic and aseptic wounds may be considered clean and dressed dry; the granulating wound or the late traumatic wound must be considered infected and unclean, and must be dressed with moist pressure dressings.

3. Newer methods in the handling of the split-thickness grafts must be measured by the yardstick of sound surgical principles. With these principles there can be no compromise.

4. Skin-grafting to resurface lost integument for the correction of contractures, and to supply adequate coverage for weight-bearing surfaces and areas exposed to trauma, may come in the field of the orthopaedic surgeon. The procedure requires infinite attention to multitudinous details in preparing the recipient area; the obtaining of the graft of a desirable thickness; perfect hemostasis; the maintenance of normal tissue tension; the prevention of tenting; the close application of a voluminous pressure dressing; and the utmost gentleness.

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NEURECTOMY TO PRODUCE ATROPHY OF THE AMPUTATION STUMP *

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Following amputation below the knee, the most satisfactory stump is one which is conical in shape and the maximum accepted length of seven to nine inches, as measured from the lower border of the patella.

The most satisfactory amputation stump observed by the author was on a young man who had extensive involvement of the muscles below the knee, due to infantile paralysis, but who had good power in the muscles of the thigh. In an effort to reproduce this type of stump, in four cases the author has divided the muscular branches of the tibial nerve to the two heads of the gastrocnemius, and in one case has also divided the nerve branch to the soleus, with very satisfactory results.

OPERATIVE TECHNIQUE

A longitudinal incision, two and one-half inches in length, is made in the lower part of the popliteal space, extending down the leg. Upon incising the deep fascia, the operator will observe the medial sural cutaneous nerve; this structure should not be damaged. This nerve may be used as a guide, to follow down into the popliteal space to the tibial nerve. The muscular branches of the tibial nerve to the two heads of the gastrocnemius are identified and completely sectioned. The branch to the soleus leaves the tibial nerve at a lower level, but is within the operative field, and may be sectioned.

Very little bleeding is encountered, but, before closure, all points of bleeding should be controlled to assure a dry field. The fascia and skin should be closed carefully to obtain a minimum amount of scar. The location of this incision is such that the scar has not been objectionable.

POSTOPERATIVE CARE

After operation, the knee is immobilized, either by traction or by a well-fitting posterior plaster splint, to facilitate healing of the wound in the popliteal space. After the amputation wound is well healed, the stump is bandaged with an elastic adhesive bandage. This support is maintained by changing the bandage every two to four weeks, until an artificial limb can be worn.

COMMENTS

The operation recommended can be carried out at the time of the amputation, after the tourniquet has been removed, by turning the patient onto his abdomen; or it may be carried out as a separate procedure, either before or after the amputation. The sural nerve and the tibial nerve should not be cut or damaged at this level, because of the danger of development of a painful neuroma.

This operation is of particular advantage in large-muscled adults, and, on the basis of limited experience, it would seem that the cases treated in this manner show a more rapid and complete atrophy of the amputation stump than others.

By producing a conical-shaped stump, this operation permits the surgeon to leave a stump of maximum length.

CASE REPORTS

CASE 1. J. K. (No. 10,114), a white male, aged forty-two, was first seen on April 24, 1941, with a swollen below-the-knee amputation stump which had not healed. On February 26, 1941, this patient had

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 23, 1946.

FIG. 1-A

FIG. 1-B

FIG. 1-C

Case 1. January 15, 1946.

sustained an injury to the right foot, which required immediate amputation. The wound had closed, but later spread open.

Physical examination disclosed a large man whose right leg had been amputated at a point eight and one-half inches below the knee. There was considerable swelling of the stump, and on the end there was a large granulating area, three and one-half by two and one-half inches in size.

The condition of the tissues was such that the stump was not suitable for re-amputation. On June 16, 1941, therefore, through an incision in the popliteal space, the muscular branches of the tibial nerve to the two heads of the gastrocnemius were sectioned. The granulating area on the stump was then covered with split-thickness skin grafts. These grafts closed the area, and the patient was discharged from the hospital on July 6, 1941, wearing an elastic bandage on the stump. On September 18 an artificial limb was applied, and the patient returned to work on January 1, 1942.

Because of a painful, thick scar over the end of the stump, the leg was re-amputated on November 25, 1942; this shortened the tibia about one inch. A new artificial limb was provided three months later.

TABLE I

MEASUREMENTS IN CASE 1*

	Apr. 24, 1941		June 13, 1941		Sept. 11, 1941		Mar. 8, 1943		Jan. 15, 1946	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Length of tibia (*inches*)	8½	14			8½	14	7¾	14	7½	
Circumference of leg (*inches*):										
At knee			13½	13½						
Lower border of patella	13	12⅞			13	13	13½	13¼	13⅜	13½
2 inches below patella			13¼	13⅜			11	13½	11⅜	12⅜
4 inches below patella			12⅞	13⅜					10¼	13⅜
5 inches below patella	13¼	13¼			11	13¼	10½	13½		
6 inches below patella			11½	12⅞			10½	12	10½	13⅞
8 inches below patella	13¼	10			9⅞	10				

*Operative procedures carried out on the following dates:
Guillotine amputation of right leg: February 26, 1941.
Neurectomy and skin graft: June 16, 1941.
Re-amputation: November 25, 1942.

FIG. 2-A

FIG. 2-B

FIG. 2-C

Case 2. December 22, 1945.

TABLE II

MEASUREMENTS IN CASE 2

	Dec. 31, 1942		Jan. 23, 1943		Mar. 11, 1943		Sept. 5, 1944		Dec. 22, 1945	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Length of tibia (*inches*)	9				9		9		9½	
Circumference of leg (*inches*):										
Lower border of patella	13½	13½							12¾	13½
2 inches below patella	12½	12¼			13		11¾		11¼	13½
4 inches below patella	13¼	12¾	12¾	13¼		14	9¾		10¼	14¾
6 inches below patella									9¼	13½
8 inches below patella	11¼	10½			10		9⅛		8	11½

Amputation of right leg: November 30, 1942.
Neurectomy: January 4, 1943.
Application of artificial limb: April 4, 1943.

FIG. 3-A

FIG. 3-B

FIG. 3-C

Case 3. January 7, 1946.

TABLE III

MEASUREMENTS IN CASE 3

	Mar. 25, 1943		June 9, 1943		Jan. 7, 1946	
	Right	Left	Right	Left	Right	Left
Length of tibia (*inches*)			9		9¼	
Circumference of leg (*inches*):						
At knee	16½	16½				
Lower border of patella					14½	15½
1½ inches below patella	13¾	14½	14½			
2 inches below patella					12½	14¾
3½ inches below patella	13½	14¾				
4 inches below patella				15	11⅝	16
5 inches below patella	13½	15½				
6 inches below patella					11¼	16
7 inches below patella	12¾	15	11			
8 inches below patella					10⅜	14

Injury to right foot: December 16, 1941.
Amputation of right leg and neurectomy: March 29, 1943.
Application of artificial limb: June 30, 1943.

On January 15, 1946, this patient returned, wearing the same artificial limb with the addition of one sock on the stump. He was working on a cattle ranch and stated that he was able to do all the work that he had done before the loss of his leg. He was able to go hunting and to walk long distances over rough ground.

The amputation stump was conical in shape, and the operative scar in the popliteal space was soft (Figs. 1-A, 1-B, and 1-C).

CASE 2. W. N. (No. 12,024) was a large white male, aged fifteen, and weighing 138 pounds. He was first seen on November 30, 1942, within a few minutes after he had sustained an extensive compound injury to the right foot. The leg was amputated; a stump, nine inches long, was left. The wound healed promptly, without infection.

On January 4, 1943, through an incision in the popliteal space, the muscular branches of the tibial nerve to the two heads of the gastrocnemius were sectioned. On April 10, 1943, an artificial limb was provided.

The final examination of this patient was made on December 22, 1945. He weighed 145 pounds, was walking without a limp, and had a painless stump. He was wearing the same artificial limb, provided four months and ten days after amputation, but was using two heavy socks. The stump was nine and one-half inches long and conical in shape (Figs. 2-A, 2-B, and 2-C), as shown by the measurements in Table II.

TABLE IV

MEASUREMENTS IN CASE 4

	Sept. 2, 1944		Oct. 17, 1944		Dec. 1, 1944	
	Right	Left	Right	Left	Right	Left
Length of tibia (*inches*)					9	
Circumference of leg (*inches*):						
5 inches above patella	20¾	21	17¼	21	19	21
Center of patella	16½	16⅝	16	16⅝	15⅞	16⅜
2 inches below patella	14½	14½	14⅛	14⅛	14⅛	14⅛
4 inches below patella	14⅛	15⅛	14	15⅛	13⅝	15⅛
5½ inches below patella	14⅝	15⅞	13⅞	15⅞	13⅛	15⅞
7 inches below patella	14⅛	15⅛	13⅛	15⅛	12⅞	15⅛

Injury to right foot: August 12, 1941.
Amputation of right leg and neurectomy: September 18, 1944.

TABLE V

MEASUREMENTS IN CASE 5

	May 20, 1945		Dec. 20, 1945	
	Right	Left	Right	Left
Length of tibia (*inches*)				7
Circumference of leg (*inches*):				
Lower border of patella		14½	15½	14½
2 inches below patella		12¾	15½	13⅜
4 inches below patella		13½	15	13
6 inches below patella		12¼	13	11¼

Amputation of left leg and neurectomy: May 21, 1945.

CASE 3. R. S. (No. 12,472) was a large white male, aged thirty-nine, who weighed 195 pounds. He was first seen on March 25, 1943, with extensive involvement of the right foot, following a crushing injury received December 16, 1941.

On March 29, 1943, the right leg was amputated nine inches below the knee, and the muscular branches of the tibial nerve to the two heads of the gastrocnemius were sectioned. An artificial limb was applied on June 30, 1943, three months after operation, and two months later the patient started to work in an apple orchard.

The final examination was made January 7, 1946, at which time he was wearing the original artificial limb well; the stump was conical in shape and in good condition (Figs. 3-A, 3-B, and 3-C). He was able to go hunting, could walk as far as twenty miles, and was employed as an automobile mechanic.

CASE 4. J. B. (No. 14,606) was a very large, white male, aged forty-seven, who weighed 250 pounds. He was seen on September 2, 1944, with a marked deformity of the right foot as the result of injuries to the foot sustained August 12, 1941. On September 18, 1944, the right leg was amputated nine inches below the knee, and the muscular branches of the tibial nerve to the two heads of the gastrocnemius were sectioned.

Traction was applied to the stump for a short time; this was followed by the application of an elastic adhesive bandage. Three months after the operation, this patient was wearing an artificial limb very well.

Up to December 1945, the patient had not returned so that additional measurements could be taken, nor had he had another fitting of the artificial limb; but he reported that he was doing the work of a laborer, without discomfort.

CASE 5. Mrs. C. C. (No. 15,657) was a large white woman, aged fifty-four. She had a spastic paralysis, involving the left arm and leg, of twenty-seven years' duration. There was a severe equinovarus deformity of the left foot, and there had been an unsuccessful stabilization operation, ten years before.

On May 21, 1945, the left leg was amputated seven inches below the knee, and the nerve branches to the two heads of the gastrocnemius and to the soleus were divided through an incision in the popliteal space.

When last seen, seven months after operation, this patient had not been able to wear the artificial leg provided enough to bring about shrinkage of the stump. The shape of the stump was satisfactory, however, as is shown by the measurements in Table V.

THE MULTIPLE INNERVATION OF LIMB MUSCLES IN MAN * †

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INTRODUCTION

It is generally recognized that the majority of the muscles of the body have a plurisegmental innervation. It is also known that many of these muscles receive more than one nerve or nerve branch. The spinal segments giving rise to the nerve fibers to the individual muscles are given in all textbooks of anatomy, with some discrepancies in the respective accounts. Given less often are the number and location of the nerve branches to the individual muscles. Probably the most complete account of these details in current editions of English and American texts on gross anatomy is to be found in that by Morris.

Attention has been called to the practical importance of a knowledge of the number and location of these branches by the work of Markee and Löwenbach [2]. Working on the dog, these authors have shown that stimulation of different nerves or nerve branches to a given muscle may involve contraction of different "segments" along the length of that muscle. If only one of the several nerves to the rectus femoris—for instance, the proximal branch—be stimulated, contraction of the proximal portion of the muscle may be accompanied by an actual stretching of the middle and distal parts of the muscle, innervated by two other nerve branches. Observations on certain patients with partial paralysis of muscles indicate that the same phenomenon probably occurs also in the human. Weakness of a muscle, associated with displacement of its bulge upon contraction, as seen in certain patients after poliomyelitis, apparently is due to stretching of a part of the muscle, and consequently to unopposed contraction elsewhere.

In the dog, according to the results of Markee and Löwenbach [3], evidence indicates that, in at least certain long muscles, the fibers composing the different nerve branches to a muscle have arisen primarily from different spinal segments. In the rectus femoris, semitendinosus, and semimembranosus, if stimulation of a ventral nerve root has produced contraction in the proximal portion of the muscle, stimulation of a more caudal root produces contraction of a more distal portion of the muscle. Information on this latter point is not available for the human; but, with these possible applications in view, a study has been made of the number, location, and pattern of branching of the nerve supply to the long muscles of the limbs.

MATERIAL AND METHODS

The observations recorded here are based upon a careful and rather complete dissection of one cadaver, supplemented and extended by the use of routine dissecting-laboratory material. Because some of the nerve branches are frequently destroyed in a routine dissection, this latter type of material has been used to supply information only about branches absent in the more careful single dissection.

During the course of this special dissection, the nerves and muscles were demonstrated and moved in front of a motion-picture camera; thus the relations from a number of viewpoints were recorded. Photographic stills were then made from selected frames,

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illustrating the innervation to each particular muscle. The drawings of the branchings to the various muscles were, in turn, made from these still photographs; and the precise relations of these nerves were again verified from the motion pictures. The figures of the nerves to the muscles we have chosen to present, therefore, depict rather exactly their location and manner of branching in one cadaver. While the authors are conscious of the variations which do occur from one individual to another, they believe this careful account of the nerve branching observed in one body will be in general more useful than a more schematized, and necessarily less exact, representation.

OBSERVATIONS

The data recorded here could logically be presented from any one of several aspects,—that is, from the standpoint of functional muscle groups, from that of anatomical location of the muscle, or from that of the nerves and their motor branches. We have chosen the latter aspect largely because of its simplicity.

The following description is derived from the dissection upon which the photographs and drawings are based. In parentheses are included data upon the nerve branching, abstracted from the texts of Cunningham and Morris. The source of the parenthetical material is indicated by *C.* for Cunningham, *M.* for Morris.

In the upper limb, the findings were as follows:

Musculocutaneous Nerve (Fig. 1)

Shortly before this nerve enters the coracobrachialis muscle, it gives off three branches to it (*M.*, one branch), two of which again branch, all entering the middle third of the muscle. As the nerve lies behind and between the two heads of the biceps, a single branch for both heads of the biceps is derived from the trunk (*M.*, one or two branches) and quickly divides into a nerve entering the upper third of each head; that for the long head divides into three branches before it enters the muscle. About three centimeters distally there arises a single branch (*M.*, one branch) for the brachialis. This divides into two branches, both of which enter the upper fourth of the muscle.

Median Nerve (Figs. 2, 3, and 4*)

The first muscular branches of this nerve supply the pronator teres (*M.*, one branch, dividing into one for each head), and arise just above the point at which the median nerve passes between the two heads of this muscle. The upper, shorter branch enters the proximal third of the humeral head of this muscle, dividing as it does so; a second branch gives off a twig to the upper third of the ulnar head and, passing distally between the heads, divides to enter the lower third of each head. As the median nerve passes between the two heads of the pronator teres, and before it passes deep to the flexor digitorum sublimis, it presents an ovoid enlargement from which several muscular branches arise. From the medial side arises the lower nerve to the pronator teres, already described; laterally arises a nerve which is distributed in part to the uppermost portion of the radial head of the flexor digitorum sublimis, the remainder passing through this muscle to enter the upper third of the palmaris longus (*M.*, one nerve). Slightly lower, from the lateral side of this swelling, arise two separate nerves for the flexor carpi radialis (*M.*, one nerve, dividing into several) which enter the upper fourth of the muscle about two centimeters apart. Immediately below the second nerve to the flexor carpi radialis there arises a second nerve to the flexor digitorum sublimis, which branches as it enters the upper part of the muscle only slightly distal to the first nerve to this muscle. A third nerve to the flexor digitorum sublimis arises from the median nerve as it courses behind the flexor digitorum sublimis. This branch enters at about the junction of the proximal and middle thirds of the muscle.

* Only the muscles whose innervation is illustrated in a given figure are labeled in that figure. Muscles removed to show deeper structures may be identified by referring to preceding figures.

The interosseous branch of the median nerve carries the remaining motor fibers of this nerve, destined for the musculature of the forearm. From the interosseous nerve arise two branches to the radial head of the flexor digitorum profundus, the upper one branched (*M.*, one or two branching). Arising close to the lower nerve to the flexor profundus is a

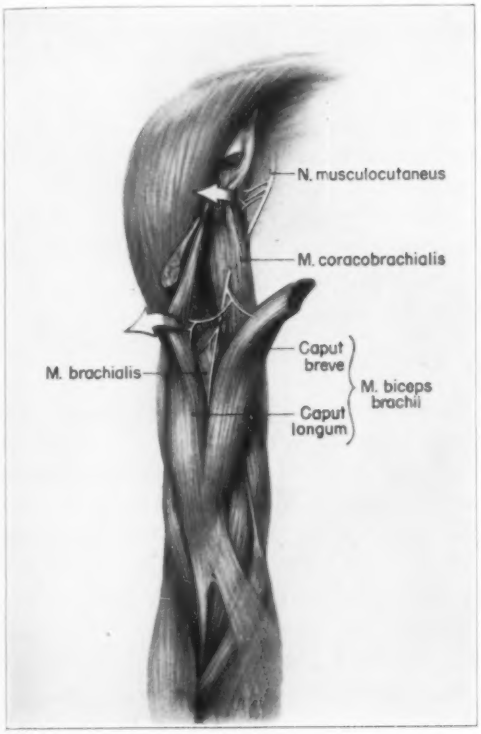

FIG. 1

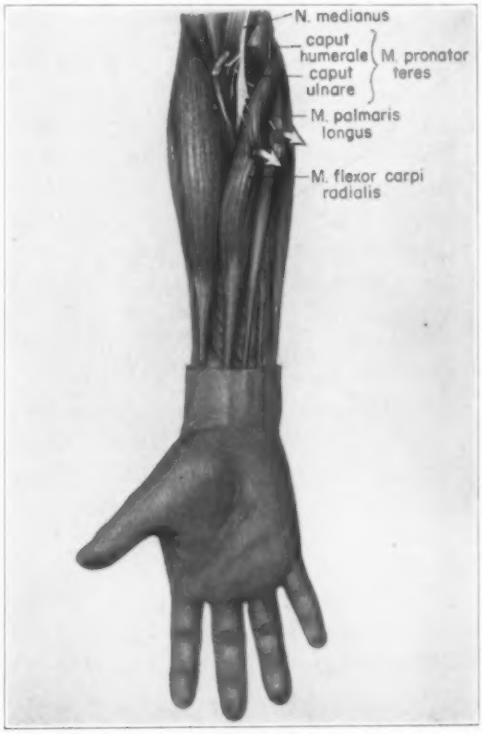

FIG. 2

FIG. 3

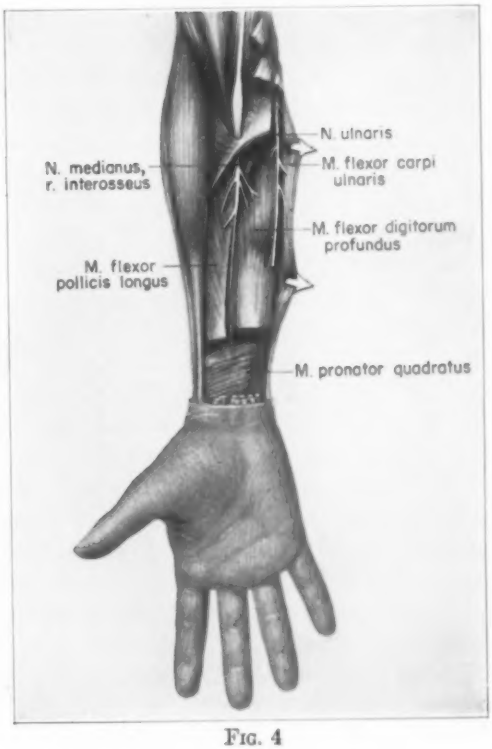

FIG. 4

branch to the upper part of the flexor pollicis longus. The interosseous nerve continues, much reduced, and gives off a second branch which enters the junction of the upper and middle thirds of the belly of the flexor pollicis longus (*M.* also describes two branches). The remaining motor fibers of the interosseus enter the deep surface of the pronator quadratus (*M.*, "branches").

Ulnar Nerve (Fig. 4)

As the ulnar nerve lies deep to the flexor carpi ulnaris, after passing between the two heads of origin of this muscle, it gives off a branch into the uppermost part of the muscle; a second branch arises just above the origin of the dorsal cutaneous branch, which in this case is quite high; a third branch to the flexor carpi ulnaris arises from the dorsal cutaneous branch, and enters the middle third of the muscle (*C.*, two to four; *M.*, two or three, or one branching). Arising from the ulnar nerve, between the first and second nerves to the flexor carpi ulnaris, is a single branch, dividing into two, entering the upper part of the ulnar head of the flexor digitorum profundus (*M.*, one branch).

Radial Nerve (Figs. 5, 6, 7, and 8)

As this nerve lies on the medial surface of the humerus, just before it enters the radial groove, it gives off its first muscular branch, to the long head of the triceps brachii (*M.*, one branch, dividing into several). Dividing into two, one of the subsidiary branches enters the long head at about the lower margin of the tendon of the teres major; the other courses farther along the posteromedial surface to enter the upper part of the middle third of the muscle.

A second muscular branch of the radial nerve, arising before this nerve disappears beneath the lateral head of the triceps, is distributed to the upper part of the lateral head. A third branch, arising just distal to this, goes to the medial head. It gives off one branch to the upper part of the medial head and then runs for a considerable distance along the medial surface of this head to enter the lower third of the muscle. Because of its course, this branch is frequently known as the ulnar collateral nerve. As the radial nerve passes between the origins of the medial and lateral heads of the triceps, on the posterior surface of the humerus, it gives off in succession a branch to the middle third of the lateral head, a stout branch into the upper lateral portion of the medial head, and a third branch entering the deep surface of the lateral head in the upper part of its lower third (*C.*, two branches to medial head; *M.*, "branches" to medial and lateral heads).

A branch from the radial nerve to the brachialis muscle was not found in this case. When such a branch occurs, it is probable, according to Cunningham, that it contains no motor fibers.

As the radial nerve lies between the brachioradialis and the brachialis muscles, it gives off a single nerve (*C.*, one or two; *M.*, one) to the former muscle. A short distance below this there arises a single nerve (*M.*, one or two nerves) to the extensor carpi radialis longus. From the point of division of the radial nerve into deep and superficial branches arises the nerve (*M.*, one nerve) to the extensor carpi radialis brevis, dividing into two, the lower branch entering about the middle of the muscle. The other nerves enter the upper third of their respective muscles.

Just before the deep radial nerve enters the supinator muscle, it gives off two branches to this muscle (*M.* mentions "branches"); in its course between the fibers of the muscle, it contributes three more twigs to it. As the deep radial nerve emerges from the lower border of the supinator, it fans out into a number of small branches. Two are given off in quick succession to about the junction of the upper and middle thirds of the extensor digitorum communis, and a single branch passes to the extensor carpi ulnaris (*M.*, one, branching into several). A third branch to the extensor digitorum communis (*M.*, one, branching into several, or two or three separate branches) and to the extensor digiti quinti

proprius passes more distally into those muscles. A branch also enters the upper part of the abductor pollicis longus (*M.*, one or more branches). The remainder of the deep radial nerve passes distally, giving off a branch into the uppermost portion of the extensor pollicis brevis (*M.*, one branch), another to the upper portion of the extensor pollicis longus, and

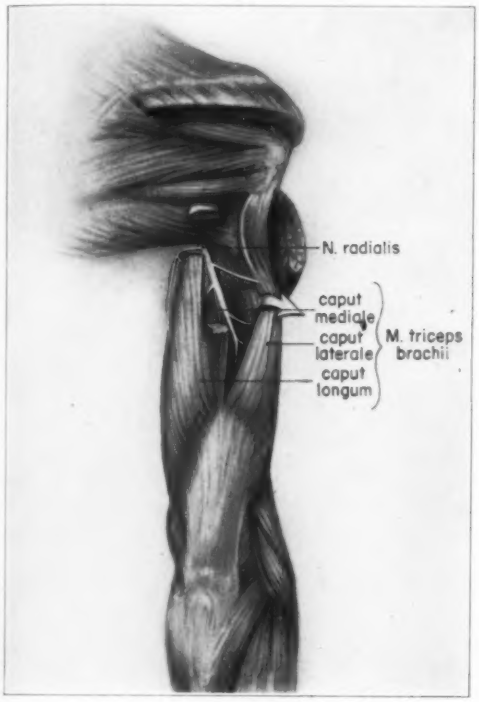

FIG. 5

FIG. 6

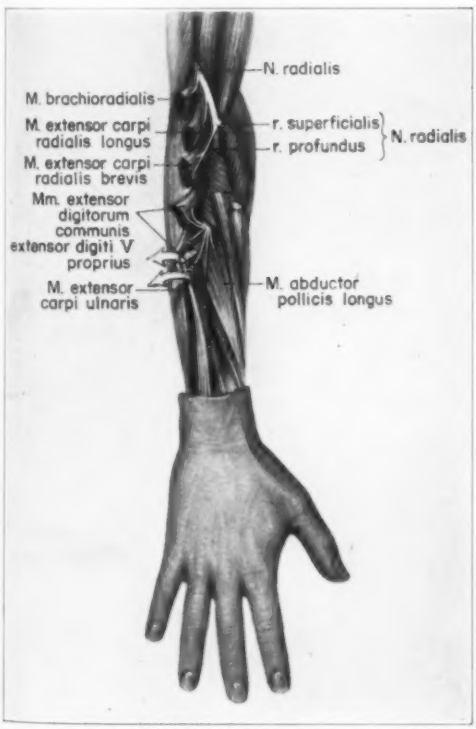

FIG. 7

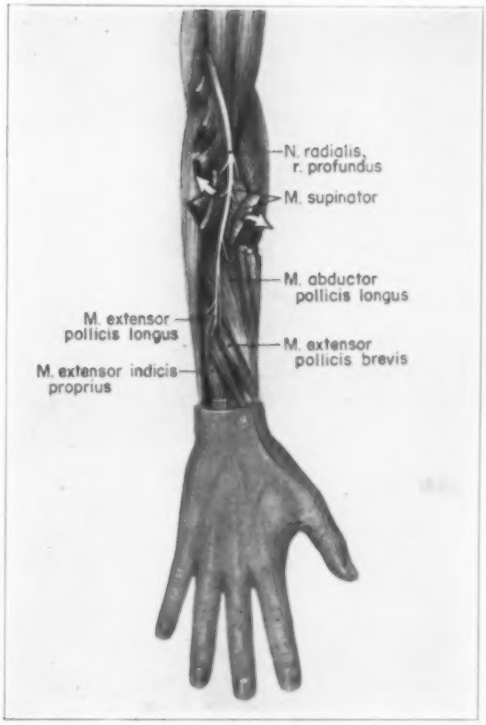

FIG. 8

another to the upper third of the extensor indicis proprius (*M.*, one branch). Its final motor branch is a second twig to the extensor pollicis longus (*M.*, one, branching into several), into its upper third.

In the lower limb, the following observations were made:

Femoral Nerve (Figs. 9 and 10)

A short distance below the inguinal ligament, this nerve divides into a number of muscular and cutaneous branches. Among the first to be given off is the small nerve to the pectineus muscle (*C.* and *M.*, one or two), passing behind the femoral sheath into the upper third of the muscle. In addition to a cutaneous branch piercing the sartorius, two branches are given off to the upper third of this muscle (*C.*, two sets; *M.*, two). The upper branch divides once; the lower branch divides into several twigs, of which the lowest enters the muscle at about the junction of its upper and middle thirds. The nerves to the rectus femoris are also two in number (*M.*, two). The upper divides to enter the upper third of the muscle; the lower in turn again divides, giving two twigs into this part of the muscle and continuing to enter the middle of the belly of the muscle. A single nerve to the vastus medialis (*C.*, two nerves; *M.*, one, branching) runs upon the medial surface of the muscle in the adductor canal; it gives off twigs into the upper part of the muscle, and continues its course to penetrate the muscle at about its middle. A single nerve to the vastus lateralis (*M.*, three nerves) divides before entering the distal part of the upper fourth of the muscle. The vastus intermedius receives a single nerve, entering the upper part of the muscle (*C.* and *M.* also mention an innervation from the nerve to the medialis, the lateralis, or both). The nerve to the articularis genu (not illustrated) is derived from the nerve to the vastus intermedius.

Obturator Nerve (Figs. 11 and 12)

As this nerve emerges from the obturator foramen, under cover of the pectineus muscle, it divides into anterior and posterior branches. The anterior branch gives off a single twig into the posterior surface of the upper margin of the adductor brevis (*M.* mentions "rami"), and then crosses superficially to this muscle. It gives off a single branch, which divides into three as it enters the junction of the upper and middle thirds of the adductor longus (*M.*, one branch, giving off several twigs; occasionally there is a second branch, probably sensory, from the femoral nerve). The remaining muscular branch of this nerve divides into three twigs, which enter the lower part of the upper third of the gracilis (*M.*, one branch).

The posterior branch of the obturator nerve passes deep to the adductor brevis, to end in four branches (*M.*, one or more) which penetrate the upper third of the adductor magnus.

Sciatic Nerve (Figs. 13 and 14)

Just below the ischial tuberosity, the sciatic nerve gives off the upper of the two nerves to the semitendinosus (*C.*, two; *M.*, two, each may be doubled). This upper nerve quickly divides into three short branches, which enter the muscle close together, about four centimeters below the tuberosity. The sciatic nerve then gives off a single branch to the long head of the biceps femoris (*M.*, two: one or both doubled, or both combined) which enters the muscle high. The upper of the two nerves to the semimembranosus (*M.*, "several" nerves) enters the deep surface of that muscle in two branches, which penetrate the muscle just below its tendon of origin, therefore close to the middle of the thigh. A further branch of this nerve passes downward on the posterior surface of the adductor magnus, sending three branches into the lower half of this muscle (*M.*, one branch).

The second nerve to the semitendinosus arises about four centimeters lower, passing unbranched into the deep surface of the muscle at about the junction of the middle and lower thirds. About four centimeters below this, the second nerve to the semimembranosus

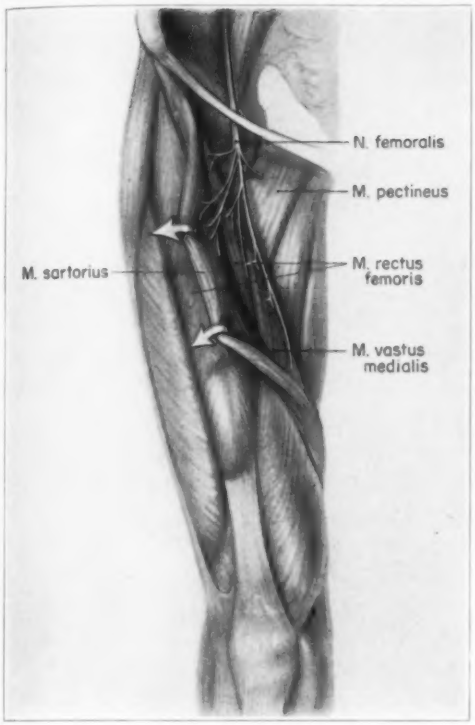

FIG. 9

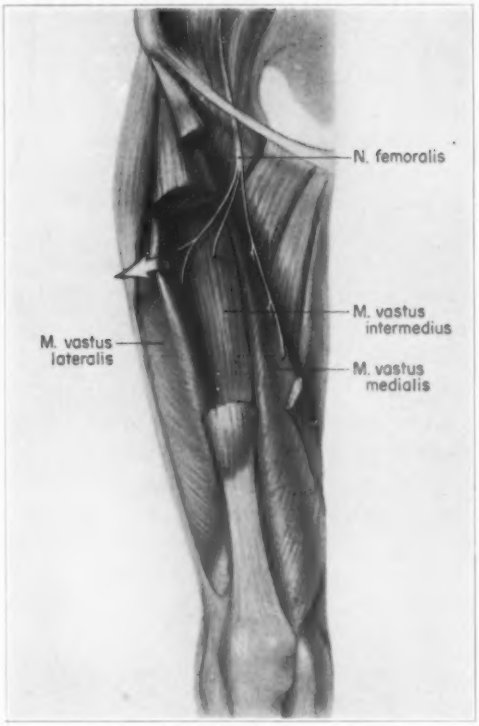

FIG. 10

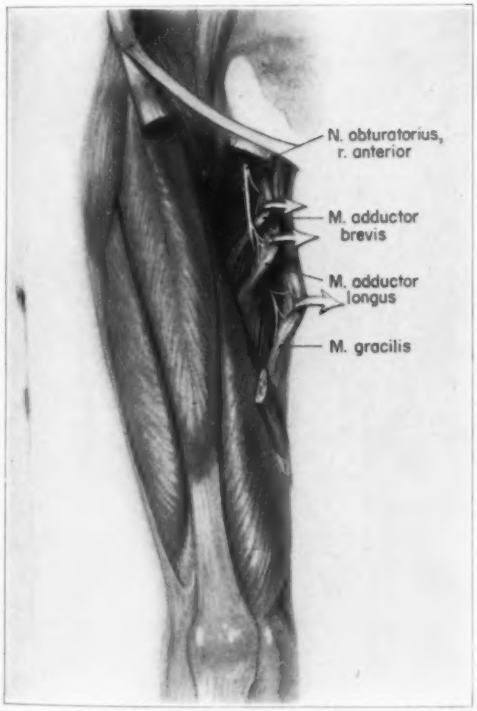

FIG. 11

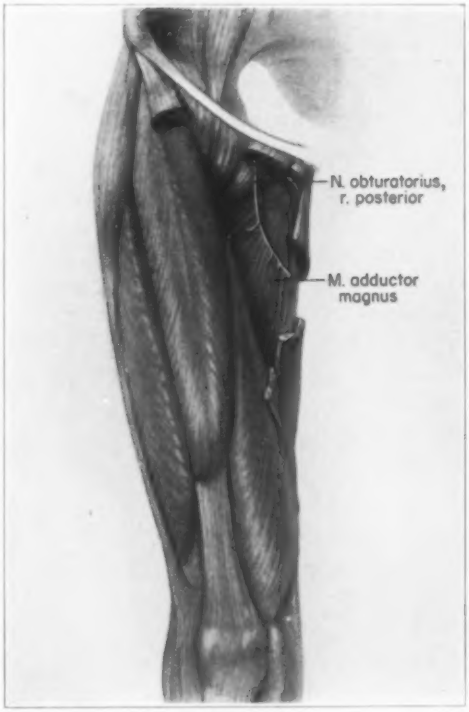

FIG. 12

is given off, dividing to penetrate the lateral edge of the muscle. Between the level of origin of these two latter nerves there arises, from the peroneal side of the sciatic nerve, the single nerve to the short head of the biceps (*M.*, one nerve), which branches once as it enters the upper part of the fleshy origin of this muscle.

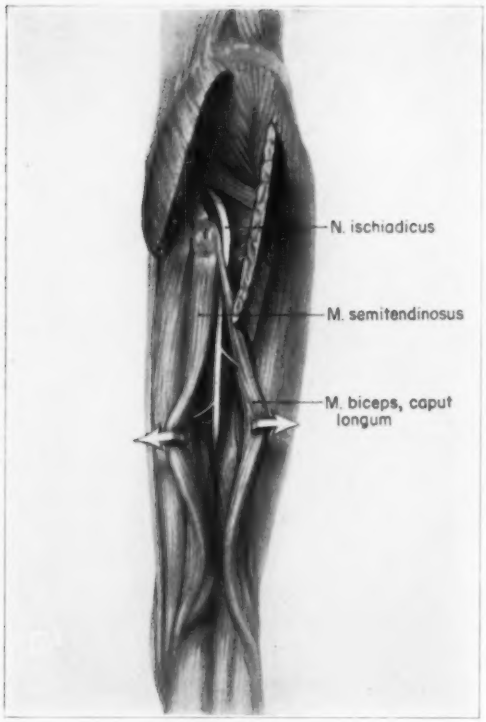

FIG. 13

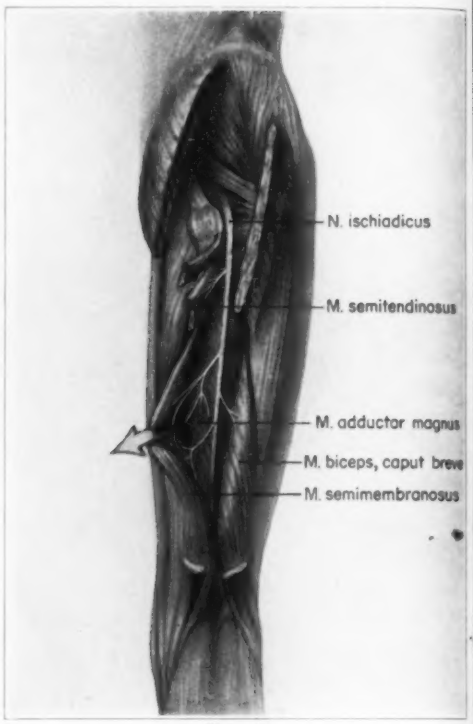

FIG. 14

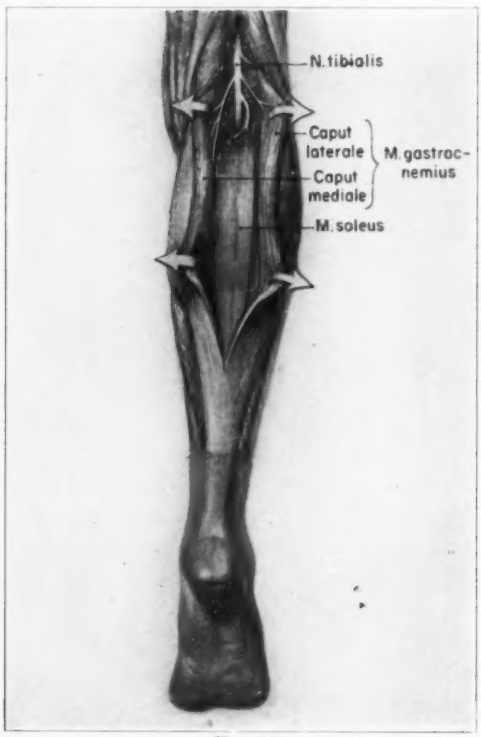

FIG. 15

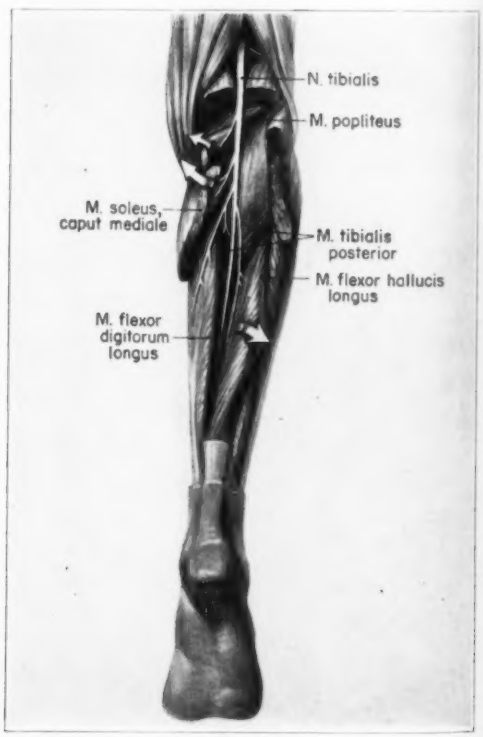

FIG. 16

Tibial Nerve (Figs. 15 and 16)

Shortly after its origin from the sciatic nerve in the popliteal fossa, the tibial nerve gives off from its anterior surface a twig (not illustrated) to the plantaris muscle (*M.*, one) and then gives off medial and lateral muscular branches, one to each head of the gastroc-

nemius (*M.*, one branch for each head). These nerves enter the heads of this muscle close to their origins; that for the medial head divides into three twigs just before it disappears in the muscle, that for the lateral head into two. Just below the origins of these nerves there arises, from the posterior surface of the tibial nerve, a single nerve which divides to supply one nerve to each head of the soleus muscle (*M.*, one nerve dividing into one for each head; also branches from the tibial nerve into the deep part of the muscle). As it lies deep to the soleus, the tibial nerve gives rise to a second branch to the medial head. This enters the muscle in two twigs.

The nerve to the popliteus (*M.*, one nerve, sometimes two) arises about the middle of this muscle, therefore above the origin of the second nerve to the soleus, and runs across the superficial surface of the popliteus to wind around its lower border and penetrate its deep surface. At the lower border of this muscle, the nerve to the flexor digitorum longus arises in common with that to the tibialis posterior. That for the posterior tibial muscle quickly separates from that to the flexor digitorum longus, and divides to enter the upper part of the muscle (*M.*, one nerve, branching). The nerve to the flexor digitorum longus (*M.*, one dividing into two: one for the medial, one for the lateral part of the muscle) also divides early, one branch entering the upper part of the muscle; the second longer branch runs for some distance upon the surface of the muscle, giving branches into it, and finally disappears into about the middle of its muscle belly.

The nerve to the flexor hallucis longus (*M.*, one or two nerves) arises shortly below the first nerve mentioned. It gives two branches into the upper part of the muscle, and a third branch runs downward on the deep surface of the muscle to disappear into its substance about the middle of its belly.

Peroneal Nerve (Figs. 17 and 18)

The superficial peroneal nerve gives off a branch to the upper part of the peroneus longus (*M.*, two) just before it passes between this muscle and the bone. As it attains the anterior side of the leg, it gives off its second muscular branch, a long slender one which

FIG. 17

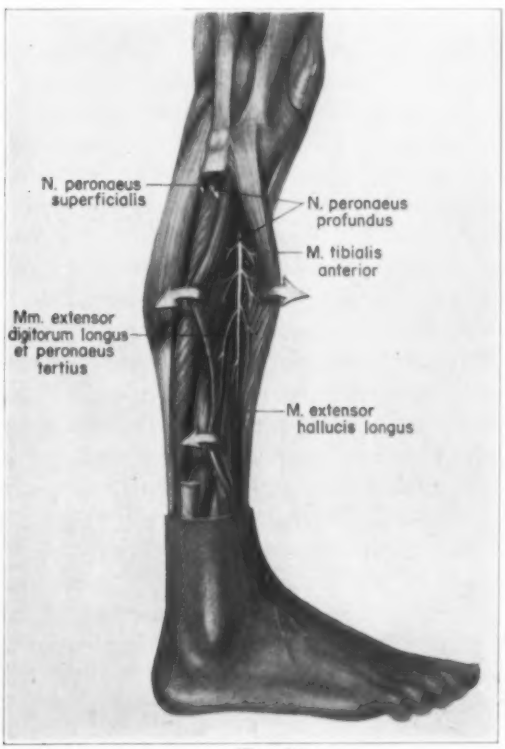
N. peronaeus superficialis
N. peronaeus profundus
M. tibialis anterior
Mm. extensor digitorum longus et peronaeus tertius
M. extensor hallucis longus

FIG. 18

runs down to the peroneus brevis (*M.*, one branch), giving several branches into the upper part of the muscle and then running along its surface to disappear in its middle third.

Under cover of the peroneus longus, the deep peroneal nerve also gives a branch into the upper part of this muscle, this branch dividing as it enters. The deep peroneal then gives off a number of separate branches to the extensor digitorum longus and to the tibialis anterior. Those to the extensor digitorum longus are three in number (*M.*, two branches). The upper two arise close together, and branch once each as they enter the upper third of the muscle; the third nerve to this muscle, arising somewhat lower, gives a branch into the middle third of the belly, and runs along the deep surface almost to the tendon before disappearing in the muscular substance. The lower nerve to the extensor longus also supplies the peroneus tertius (*M.*, one). There are also three nerves to the tibialis anterior (*M.*, one with several twigs from common peroneal nerve, one from deep peroneal nerve). The upper two enter the upper third of the muscle, both branching before entering; the lower nerve gives a branch into the middle third, and runs some distance before finally disappearing into the lower third of the muscle.

A single nerve into the upper third of the extensor hallucis longus (*M.*, one nerve), branching as it enters, completes the muscular branches of the peroneal nerves in the leg.

DISCUSSION

Of the fifty-eight separate heads of origin of the long muscles of the limbs which we have considered here, all but fifteen were penetrated by nerve branches at more than one point. This was true of the one body described and illustrated here; ten of these fifteen are known to receive more than one nerve branch in other individuals.

Included in the cases of muscles receiving more than one nerve branch are both those to which two or more nerves arise separately from the main nerve trunk, and those to which the two or more entering nerves are derived from a single stem. These two apparently different conditions are in reality only the result of varying types of fasciculation, for in some bodies the nerves arise separately, while in others they are bound together in a common sheath of connective tissue.

Many of the longer muscles receive their nerve supply at two rather distinct levels, one nerve branch penetrating the muscle close to its origin, other branches entering the middle or, rarely, the distal third. This anatomical pattern is similar to that in the dog, in which experiments on certain muscles have shown that the nerves entering at different levels control different "segments" along the length of the muscle. If experimental data are to be obtained in the human by nerve stimulation, this pattern of branching suggests the muscles upon which such observations might most fruitfully be made.

However, it should be pointed out that the manner and position of entrance of the nerves to a muscle give little evidence of the distribution of these nerves within the muscle. In the case of the adductor magnus, it would seem fairly obvious that the obturator nerve controls, in general, a proximal part of the muscle, and the sciatic nerve, in general, a distal part. A different type of distribution is illustrated by the nerve supply to the flexor digitorum profundus; it is well known, both anatomically and clinically, that an ulnar portion of this muscle is supplied by the ulnar nerve, a radial portion by the medial nerve. For most muscles, even such apparently simple conclusions cannot be reached from observation of anatomical material. In the rectus femoris of the dog, for instance, the three nerves entering the muscle do control upper, middle, and lower "segments" of this muscle; however, these segments are roughly triangular in shape, the upper and lower segments nearly meeting each other. Moreover, judging by the results of stimulation in the dog, the extent of a muscle controlled by a given nerve branch bears no precise relation to the relative size of this entering branch. Perhaps this may be due to variations in the number of sensory fibers included in the various nerves.

Many of the muscles, although they receive several branches, receive these very close

together, and thus the external pattern of branching gives no evidence whatever of their distribution within the muscle. One can also only speculate concerning the functional distribution of the nerve fibers to those ten muscles in this body which we found to receive only a single unbranched nerve, but which in other bodies may receive more than one branch.

The existence of multiple nerve branches in the human, and the fact that in the dog different parts of the muscle contract on stimulation of different ventral spinal roots, might at first thought be interpreted to mean that the different branches supply regions of the muscle developed from different somites. It should be remembered, however, that neither experimental embryological evidence nor observations on the developing human embryo support the hypothesis that the limb muscles are derived from somites; the experimental evidence in the *Amphibia*, for instance, indicates clearly that the limb muscles in these forms are derived from unsegmented lateral mesoderm. The segmental innervation of the limb as a whole is of course evident; however, the relations between the developing nervous and muscular systems are certainly as yet not fully understood, and further discussion of the known facts would be out of place in this paper.

It might also be pointed out that the number of nerve branches entering a muscle bears no fixed relation to the number of spinal-cord segments which are said to innervate that muscle. The individual muscles of the limbs are regularly supplied through from two to four spinal nerve roots; the variations given for any one muscle by different authors may reflect real variations between individuals, the paucity of our knowledge, or both. There is not the slightest evidence that the variations in the nerve branching to a muscle are correlated with the segmental nerve supply to that muscle.

It would be tempting to try to correlate the observations presented here with various clinical conditions. Yet, as the data presented here are based upon experiments on the dog and observations on the human cadaver, any speculation concerning their clinical significance would seem at this time to be premature.

SUMMARY

Experimental evidence from the dog, demonstrating the physiological importance of the multiple innervation to individual muscles, led to the detailed observations, here presented, upon multiple nerve branches in the human. Of fifty-eight separate heads of origin of the long muscles of the limbs in one cadaver, all but fifteen were entered by nerve branches at more than one point. Ten of these fifteen are known to receive more than one branch in other individuals. These multiple branches may enter the muscle close together, or may be distributed for some distance over the length of the muscle. In neither pattern of branching can the ultimate distribution of the nerve fibers within the muscle be deduced from a purely morphological study.

The evidence obtained from experiments on the dog by Markee and Löwenbach demonstrates that the multiple nerves entering a muscle may control the contraction of different "segments" along the length of the muscle. The present study has emphasized that a similar anatomical condition exists in the human. However, physiological evidence similar to that for the dog has yet to be obtained.

NOTE: It is a pleasure to express our indebtedness to Mr. Elon Clark and his co-workers in the Division of Medical Illustration for their artistic and accurate drawings.

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ACTIVE SPLINTING OF THE HAND *

BY STERLING BUNNELL, M.D., SAN FRANCISCO, CALIFORNIA

Hands are peculiar in that they are prone to become stiffened,—evidently because the joint surfaces are so accurately approximated, and there are more close-fitting, gliding parts than elsewhere in the body. Joint ligaments are just long enough, but not too long. If, from any cause, a hand remains swollen and immobile, the serum-soaked ligaments become short and thick, binding the joints. From the fluid of oedema, fibrin settles between the movable tissues and within them,—muscles, tendons, and joints alike. Fibroblasts invade; the whole becomes organized and shrinks; and the hand becomes congealed. The proximal joints of the fingers stiffen in the straight position, because of their collateral ligaments. These ligaments are tight in flexion, but shorten when they are relaxed, with the joint in the straight position, in such a way that they prevent flexion.

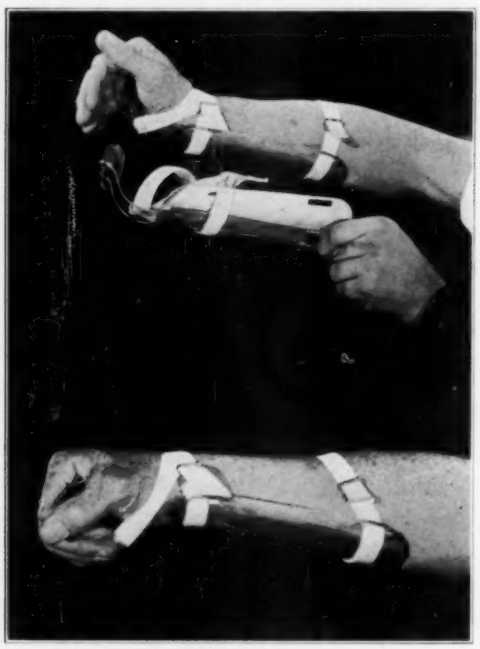

FIG. 1

Cock-up splints of flat spring steel or piano wire, used to dorsiflex wrist and furnish exercise. Upper view shows wrist in dorsiflexion; lower view, in flexion.

Splints cause stiffness of the hands if they extend beyond the distal crease in the palm to include the digits, if they are kept on too long, if they hold a joint in a rigid, strained position, or if they hold the hand in a position of non-function. Errors of position in splinting are to hold the wrist flexed, the fingers straight, the palm flat, and the thumb at the side of the hand or pressed close into it.

The wrist is the key joint to the position of function. When held flexed, in the protective position assumed by a sick hand, the extensors of the digits are tightened, hyperextending the proximal joints of the fingers, drawing the thumb back and to the side of the hand, flattening the metacarpal arch, and secondarily, from the flexors, producing clawing of the fingers. The intrinsic muscles are then too far off center to act. Shortening of the muscles from disuse exaggerates the effect. The muscles are in balance in this position of non-function; but, if we dorsiflex the wrist, they will be in balance in the position of function. The position assumed by the hand is determined by muscle balance, which changes with the position of the wrist. In examining many patients who were brought from overseas with their hands in plaster, it was rare to find a dorsiflexed wrist.

The injured hands which were found to be limber were those in which the wounds had been closed quickly; in which only the injured part of the hand had been immobilized, and for but a short time; in which the position of function had been maintained, especially with the proximal joints in flexion; and in which movement had been active and continuous.

Splints which are used to immobilize inflamed or healing parts—such as occur with osteomyelitis, fractures, or after plastic surgery—must of necessity be stationary. In this paper a system is outlined of using elastic splinting or spring splinting to coax joints around

* Presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1946.

FIG. 2

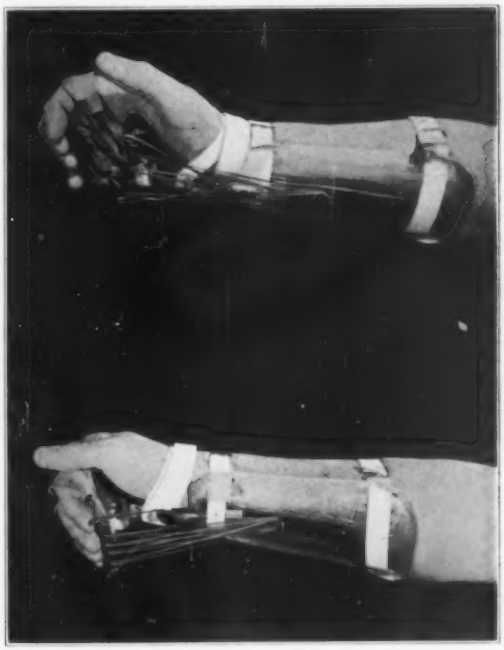

FIG. 3

Fig. 2: Splint to flex and exercise proximal joints of fingers. Direction of pull of rubbers is adjusted by bending outrigger.

Fig. 3: Metal spring splint with outrigger, over which has been slipped metal tubing to act as a roller, bent to give the desired direction of pull of the rubbers. Upper view shows dorsiflexion of wrist and extension of proximal joints of fingers. Lower view shows flexion of wrist and of proximal finger joints.

from the position of non-function into that of function, and to maintain them so. Spring splints are also advised as a substitute for paralyzed muscles in peripheral-nerve injuries.

In forcing joints into other positions, spring or elastic splinting has been found to be more efficient than unyielding splinting. Rigid splinting makes rigid hands. In splinting with springs or elastics, the joints are never strained to excess, nor are they immobilized. Active splinting is physiological splinting. Hands need mobility to thrive. If kept still, they become atrophied and stiff. The hands work continuously against the springs or elastics; and, with these splints, they are actually exercised. By this system we splint to

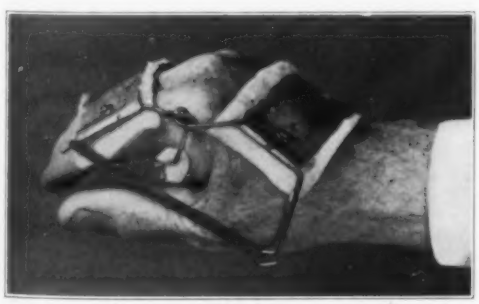

FIG. 4

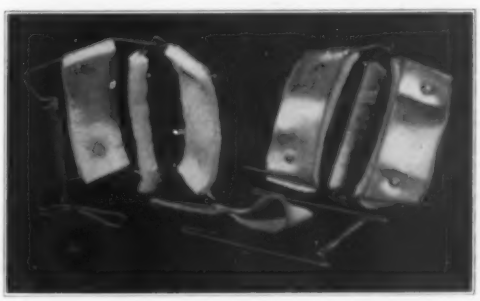

FIG. 5

Fig. 4: Illustrates knuckle-bender splint, which has been designed to flex and exercise proximal joints of fingers. The splint has three padded points of pressure, activated by rubber bands and with pivots corresponding to the axes of the joints. Motion is carried through the full range. Rubber on back of the thumb helps to oppose it.

Fig. 5: Shows knuckle-bender splint, with leather loop and rubber to draw the thumb into opposition. Note the outrigger with tube roller, over which leather loops and rubber bands draw the fingers into extension in the correction of claw-hand.

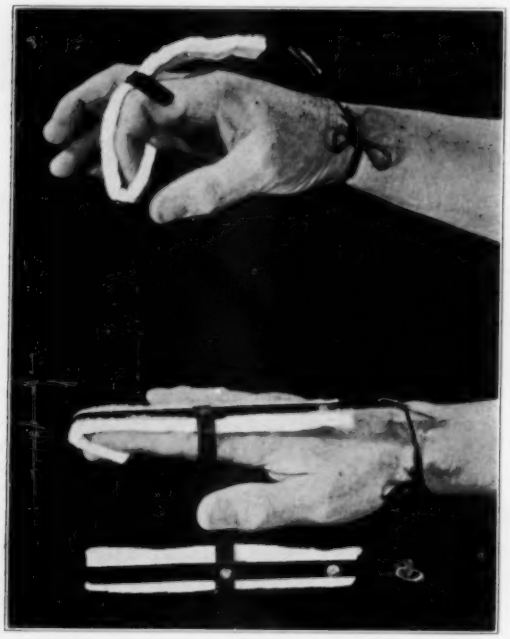

FIG. 6

FIG. 7

Fig. 6: Simple splint of clock spring, to draw fingers into extension. The range of motion is demonstrated.

Fig. 7: Safety-pin splint of spring wire (0.033 inch) to straighten finger. The two views show the spring motion.

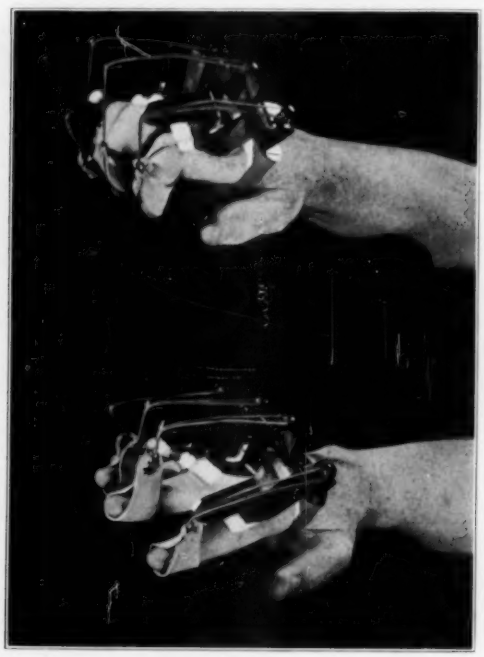

FIG. 8

FIG. 9

Fig. 8: Splint of clock spring, designed to extend and exercise the fingers (developed at Dibble General Hospital).

Fig. 9: Modified Oppenheimer splint, used to balance the muscles in cases of radial palsy. The main spring wires are light (0.069 inch). The thumb is held by a leather loop and light spring wire (0.033 inch) instead of a rigid ring, so as to give free mobility. Strap passes through wire rings to retain splint in place. Upper and lower views show motion possible.

mobilize, not to immobilize. It is functional splinting. The muscles pump away their stagnant fluids, washing out the toxins; the tendons keep gliding and the joints keep moving, thus preventing adhesions and keeping these structures normal.

In active splinting, the splints should be light, and should not interfere with occupational therapy or other work. They force the joints around into the position of function,—that is, the wrist into dorsiflexion, the proximal joints of the fingers into flexion, the palmar arch into a curve, and the thumb into the position of opposition. Also, the splints extend clawed fingers. In the position of non-function a little motion is useless; but in the position of function, motion is useful for pinching and for picking up objects. When a hand can do this, it will be used more and more, and will continually improve with work.

SPLINTING FOR PARALYSIS

Paralytic patients have been oversplinted. The dictum formerly was to keep the paralyzed muscles fully relaxed by splinting unremittingly in the position opposite to that of the deformity. So many hands have been crippled from overcorrection and stiffened from rigid splinting that some neurosurgeons have rejected all splinting in cases of paralysis. This is going too far in the other direction. Without splinting, the paralyzed muscle becomes too long. The deformity from muscle imbalance eventually becomes fixed. Then, after the nerve recovers and reinnervates the muscle, it has the additional task of shortening the muscle against deformity and against the pull of a strong antagonist. It is unnecessary to keep the paralyzed muscle in full relaxation; merely to keep it in the position of function is sufficient. No splinting is needed, except for the specific muscles involved; all other parts of the hand should be free for activity. The object should be to supply a spring or elastic pull, of just sufficient degree to serve as a substitute for the paralyzed muscle, to maintain muscle balance in the position of function. The splint should be as light as pos-

FIG. 10

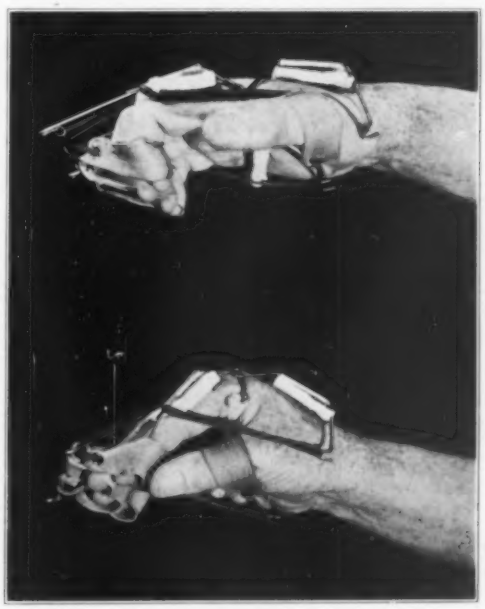

FIG. 11

Fig. 10: Suspension splint for radial palsy (Thomas) to furnish muscle balance and complete freedom of action for manual work. The spring wire which holds the thumb is very light. Degree of motion is demonstrated.

Fig. 11: Knuckle bender, used in palsy of both median and ulnar nerves to correct muscle balance by substituting for paralyzed intrinsic muscles. Upper view shows position of claw-hand, with thumb at the side and proximal finger joints straight. In lower view, position has been corrected by elastic pull of rubber bands, straightening clawed fingers, flexing proximal joints of the fingers, drawing the thumb into opposition, and curving the metacarpal arch. Outrigger with tubing roller has been snapped into place.

sible, and should allow free, unhampered use of the hand for manual work. Such a spring splint exercises all of the muscles. For radial palsy, if a man keeps his hand always in supination, the extensor muscles will be protected by gravity, making splinting unnecessary; but the patient will not always maintain this position and, without supination, his hand will not fall into dorsiflexion.

The principle of active splinting, although developed for the hand, is applicable to other joints. For example, after the acute phase has passed in poliomyelitis, we need just enough spring substitution to complete the muscle balance and still allow free exercise of the limb.

DISCUSSION

Dr. Philip D. Wilson, New York, N. Y.: This system of splinting which Dr. Bunnell has demonstrated is extremely ingenious. It is the result of many years of thought and study. Many of us cannot even understand the full implication of some of these splints and what they do. Because Dr. Bunnell has worked through the various main centers of the Army, he has been able to multiply his own efforts so that relief has been brought to many hundreds of men with crippled hands. I visited one of these centers and was greatly impressed by the work there. I am very sorry that General Kirk is not here to discuss this paper and to express the gratitude which we all feel toward Dr. Bunnell.

A STUDY OF SUPINATION AND PRONATION, WITH ESPECIAL REFERENCE TO THE TREATMENT OF FOREARM FRACTURES *

BY JAMES PATRICK, F.R.C.S., GLASGOW, SCOTLAND

From the Orthopaedic Department, Glasgow Royal Infirmary

This study is based on a series of about 6,000 fractures of the forearm treated during the last eleven years, and on a small number of non-traumatic cases with limitation of rotation due to other causes. Only a portion of the fracture cases had more than slight limitation of rotation; 1,245 such cases were especially investigated and followed up, and these formed the major part of this work.

Rotation is the movement mainly affected after union of forearm fractures, and yet this important function is very often neglected in the treatment of these cases. Good pronation is necessary in eating with a knife and fork, in typing, and even in as fundamental an action as picking up a small object. Full supination is needed for such everyday actions as accepting one's change in the bus or wielding a shovel. Different patients have their own peculiar complaints associated with loss of supination; a violinist will find it impossible to play if his left forearm is affected, and a farmer's wife will explain how difficult it is to milk a cow. It is possible to compensate partly for loss of pronation by abducting the humerus, but limitation of supination does not admit of ready compensation by any such manoeuvre.

Observations of normal people reveal marked individual variations in the range of supination and pronation, even though the range in both forearms of any single individual is identical. The range of rotation seems to decrease with age. Pronation shows the greater individual variation, and in normal adults its range may be as little as 30 degrees. Supination, on the other hand, is rarely less than 70 degrees.

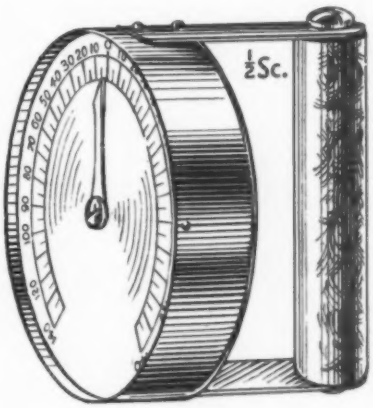

FIG. 1

Goniometer for measurement of supination and pronation. (*Reproduced by permission from the British Medical Journal, Aug. 19, 1944.*)

CLINICAL MEASUREMENT OF SUPINATION AND PRONATION

In order to make comparative clinical measurements of supination and pronation, a special goniometer was devised (Fig. 1). The pointer of the instrument is fastened to a spindle, running through the axis of the drum; a weighted lever, fixed on the spindle inside the drum in a position diametrically opposite the pointer, keeps the pointer vertical as the drum with the scale rotates. Zero position is taken when the handle of the instrument, which the patient grasps, is vertical and in line with the humerus.

Direct measurements of the range of supination and pronation are valueless for comparative purposes, since the range of rotation may vary enormously in different individuals. One must always read the range of supination and pronation on right and left arms and record the limitations of supination and pronation as minus x and minus y degrees, respectively. In pronation, the patient tends to abduct the elbow and so to falsify the reading; this error must be guarded against. In supination, the patient may lean toward the injured side; and, to get an accurate reading, this error must also be checked.

* Based on a paper given at a meeting of The British Orthopaedic Association in Glasgow, June 1943, and on a Hunterian Lecture delivered at the Royal College of Surgeons of England, at London, May 31, 1945.

THE MECHANICS OF SUPINATION AND PRONATION

The movement of the radius around the ulna is like that of the handle of a bucket. The head of the radius pivots in the annular ligament, while the lower end swings around the head of the ulna, being attached to it by the articular disc.

The fibers of the *interosseous membrane* run downward from the radius to the ulna. During pronation of the forearm, the radius moves downward slightly in relation to the ulna, so that the fibers of the interosseous membrane tend to be slack.

FIG. 2

The *axis of rotation* of the radius passes through the center of the head of the radius at the upper end; at the lower end it passes through the head of the ulna at a point close to the base of the ulnar styloid. When this axis is drawn on an anteroposterior roentgenogram of the forearm bones, it is found to pass exactly along the interosseous border of the ulna (Fig. 2). In a lateral roentgenogram, the interosseous ridge of the ulna is usually found to lie slightly behind the axis of rotation. The sectional relation of the axis of rotation to the interosseous border of the ulna is shown in Figure 3. It will be seen from this diagram that the fibers of the interosseous membrane tend to become tightened during pronation and slackened during supination. This effect, due to the axis of rotation lying in front of the interosseous membrane of the ulna, is exactly balanced by the opposite

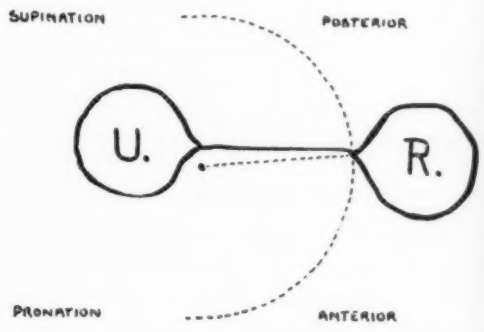

FIG. 3

Fig. 2: Roentgenograms of normal radius and ulna, with wire drilled along axis of rotation of radius.

Fig. 3: Sectional diagram of radius and ulna, showing arc of rotation of radius as a dotted line, with interosseous ridge of ulna lying just behind center of rotation.

tightening-slackening effect of the slight piston movement of the radius during pronation and supination; as a result, the interosseous membrane retains equal tension throughout the full range of rotation. In other words, for all practical purposes, one can disregard the slight piston movement of the radius and the slight displacement of the interosseous ridge of the ulna behind the axis of rotation, because the effects of these two factors on the interosseous membrane balance one another. The interosseous border of the ulna can then be regarded as actually corresponding to the line of the axis of rotation of the radius,—at least for the purpose of simplifying this study of supination and pronation.

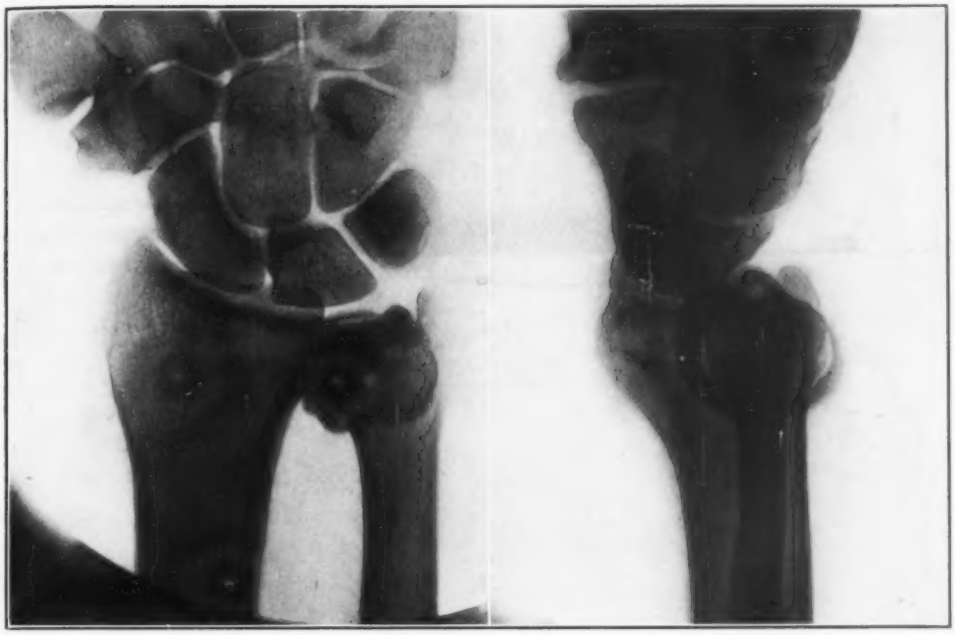

FIG. 4

Normal arthrograms of inferior radio-ulnar joint.

The *triangular fibrocartilage*, or articular disc, is the main ligament binding the lower end of the radius to the ulna. At its base the articular disc is attached to the radius; at its apex it is inserted into the radial aspect of the styloid process of the ulna. From its other two sides, capsular fibers pass to the anterior and posterior surfaces of the head of the ulna. The articular part of the carpal surface of the head of the ulna consists of a small triangular area of cartilage, occupying the sector adjacent to the radius. The remaining two-thirds of the head give rise to lax fibers, which blend with the triangular fibrocartilage. A moment's consideration will show that, in supination and pronation, the articular disc will glide to and fro over the head of the ulna. Figure 4 shows the appearance of normal arthrograms of the joint space between the head of the ulna and the fibrocartilage.

Normally, pronation is limited by the crossing of the radius on the ulna and the trapping of the deep flexor muscles of the forearm between these two bones. The normal limiting factor in supination is more difficult to ascertain, but it appears to be caused by the posteromedial edge of the lower end of the radius becoming impinged against the tendon of the extensor carpi ulnaris, as it lies in its groove.

LIMITATION OF ROTATION FOLLOWING UNION OF FOREARM FRACTURES WITHOUT DISPLACEMENT

A consecutive series of 637 forearm fractures, excluding any with imperfect reduction or malalignment, was studied; and, once firm union had occurred, measurements were made of supination and pronation. Figure 5 shows the average combined limitation of supination and pronation for fractures of the radius and ulna, respectively, at the different levels. It will be seen from this graph that, with the exception of some fractures of the head of the radius, fractures above the level of the interosseous membrane do not cause limitation of rotation, once union has occurred. Fractures of the radial styloid are also in this category.

Colles's Fracture

In patients with Colles's fracture, limitation of rotation develops; this persists for many months and is sometimes permanent. These patients have pain over the head of the ulna when supination or pronation is forced.

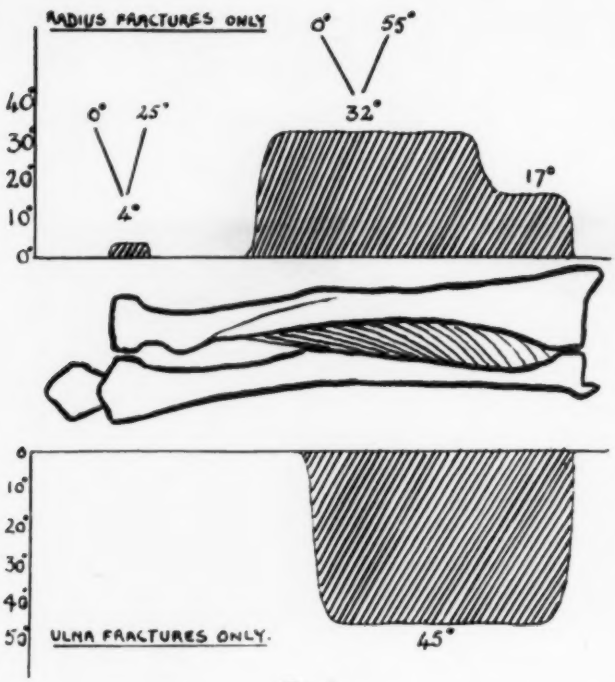

FIG. 5

Graph, based on 637 cases, shows average limitation of rotation in fractures at different levels.

When displacement of a Colles's fracture occurs, a strain is put upon the articular disc. Either this disc ruptures or, more frequently, the styloid process of the ulna, to which the triangular fibrocartilage is attached, is fractured at its base and displaced laterally to the same extent as the lower fragment of the radius. When reduction is effected, the semirigid articular disc pushes the ulnar styloid back into position. When the fibrocartilage is displaced, the capsular fibers passing from it to the head of the ulna are torn. Healing of this torn capsule results in adhesions and fibrosis, and a good deal of the joint space between the articular disc and the head of the ulna may be obliterated.

As a result of these changes, the triangular fibrocartilage can no longer glide freely to and fro on the head of the ulna during supination and pronation; and thus the limitation of supination and pronation and the associated pain are produced. Some degree of fibrosis may also extend directly between the radius at the site of the fracture and the lower end of the ulna, but this is not the main factor in causing limitation of rotation.

Investigation of this problem was done first by taking arthrograms of the joint space between the head of the ulna and the fibrocartilage. Uroselectan was injected through a needle passed from the dorsum of the wrist, and the joint was distended with the opaque medium. Figure 6 shows the appearance in a patient who had 90 degrees of limitation of supination and 40 degrees of limitation of pronation, nine months after reduction of a Colles's fracture. In all the cases of Colles's fracture with limitation of rotation which were investigated, some degree of obliteration of this joint space could be demonstrated.

Because the main displacement of the lower radial fragment is backward, it is to be expected that the anterior part of the capsule will be damaged more than the posterior part, and supination might be expected to be more limited than pronation. Measurements showed that limitation of supination was usually twice as great as limitation of pronation. The degree of limitation of supination and pronation is quite unpredictable. There appears to be no relation between the degree of the original displacement and the extent of loss of rotation, nor does perfect reduction necessarily ensure a full return of rotation.

Further study into the cause of limitation of rotation was done on twenty-four patients subjected to operation, and the dissections confirmed what had been inferred from the arthrograms. In no instance was any arthritic change found in the cartilage of the lower end of the ulna.

Fractures of the Head of the Radius

Most fractures of the head of the radius produce no limitation of rotation. The ones which do are usually those with comminution or marked displacement,—in other words, those subjected to operation. There is no doubt that excision of the whole head is better

FIG. 6

FIG. 7

Fig. 6: Arthrogram of lower radio-ulnar joint in a case of old Colles's fracture with marked limitation of pronation.

Fig. 7: The upper roentgenogram shows a typical fracture of the head of the radius with dislocation of the elbow. The lower roentgenogram, taken a year after complete excision of the head, shows the new-bone formation on the anterior aspect of the neck.

than excision of a fragment of the head of the radius. Even with careful excision of the whole head, most patients have varying degrees of limitation of rotation, and in many cases this loss is considerable. Some limitation of extension of the elbow also frequently results.

The worst results occurred in those cases in which fracture of the head of the radius was associated with posterior dislocation of the elbow. There were seven such cases in this series. Closed reduction of the dislocation was done, and the head of the radius was then excised. In all cases a mass of callus formed on the anterior aspect of the neck and infiltrated into the adjacent muscles (Fig. 7); there was consequently a severe restriction of rotation, as well as of extension. In the uncomplicated fractures of the head of the radius treated by excision, callus formation was singularly absent; and any limitation of rotation which occurred was due to adhesions between the joint capsule and the raw bony surface of the neck.

It has been rare to find any complaint of pain at the wrist due to damage to the articular disc, either before or after excision of the head of the radius; and while an injury to the fibrocartilage may occur, it is seldom of any clinical significance.

Fractures of the Radius and Ulna at the Level of Attachment of the Interosseous Membrane

Since the normal range of pronation is checked by the radius crossing over the ulna and compressing the deep flexor muscles between the two bones, anything encroaching upon this space, such as fibrous tissue, callus formation, or oedema and hemorrhage, will alter the compressibility of the flexor muscles and limit pronation. It is therefore to be expected that, in all fractures of the middle third of the radius or ulna, some loss of

pronation will ensue and will last for a considerable time after union has occurred. Assessment of the other factors limiting rotation is therefore based upon measurements of supination rather than of pronation.

Isolated Fractures of the Ulna

Some degree of loss of rotation is present for a time after union of all ulnar fractures at the level of attachment of the interosseous membrane. Fibrosis or callus rarely extends far enough to involve the radius, and so limitation of rotation must be due to some other factor. The obvious cause is fixation of the adjacent interosseous membrane in the callus and fibrous tissue. Figure 8, *A* shows how this loss of rotation is brought about. The segment of interosseous membrane involved must tighten in supination and in pronation, and so restrict these movements.

In actual practice, the restriction of rotation in isolated ulnar fractures is rarely permanent; in most cases, a return to almost full rotation occurs. This is probably due to the fact that isolated fractures of the ulna are usually displaced very little; the articular-disc attachments and the ulnar styloid usually escape damage (see section on *Isolated Fractures of the Radius*); any limitation of rotation is not associated with much pain, and therefore the affected tissues are stretched by the patient's constant efforts at rotation.

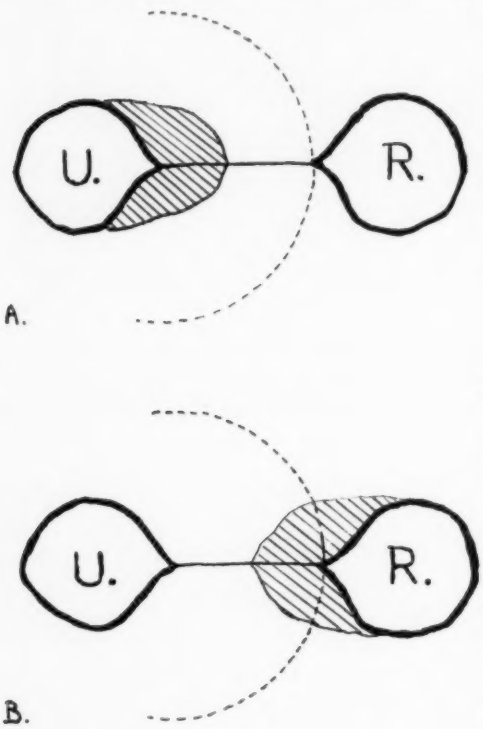

FIG. 8

Diagrams to illustrate how fixation of the interosseous membrane by callus or fibrosis around the ulna restricts the range of rotation; but around the radius the range of rotation is not restricted.

Isolated Fractures of the Radius

A study of these cases shows that they may be divided into two distinct classes: Group 1 includes those with no loss of rotation (except for slight loss of pronation, as explained previously), and Group 2 includes those with definite loss of rotation.

Figure 8, *B* shows that callus or fibrosis, extending into the interosseous membrane from the radius, cannot affect the range of rotation of the radius. What, then, is the explanation for the loss of rotation in the cases in Group 2? In those cases it is found that the attachments of the articular disc are torn. Upon forcing rotation, the patient complains of pain at the head of the ulna; the cause of the limitation of rotation is, in fact, precisely the same as in Colles's fracture,—namely, adhesions, fibrosis, and shortening of the attachments between the triangular fibrocartilage and the ulna. The partial obliteration of the joint space between the triangular fibrocartilage and the head of the ulna can be demonstrated readily by arthrogram (Fig. 9). In this arthrogram, done on a patient who had sustained a fracture of the mid-shaft of the radius, the partial obliteration of the joint space is apparent. A rupture of the articular disc, close to its radial attachment, had occurred; and the uroselectan may be seen, passing through the gap into the wrist joint. This type of rupture of fibrocartilage is more common in fractures of the shaft of the radius than in Colles's fractures, where fracture of the ulnar styloid is the usual associated injury.

Isolated fractures of the shaft of the radius, with displacement, demand careful treat-

ment. They are peculiarly apt to become redisplaced in plaster, even when a perfect reduction has been accomplished; and the redisplacement is accompanied by a dislocation at the inferior radio-ulnar joint, since the main ligament (the articular disc) holding the bones in relation to each other is often avulsed. Certainly, where the fracture line in the radius is oblique, open operation and fixation of the fragments by an inert metal screw or a plate should be done. The operation will cause some increase in the fibrous-tissue reaction around the fracture; but any further involvement of the interosseous membrane from the radial side will not affect the range of rotation.

FIG. 9

Arthrogram of the inferior radio-ulnar joint in a case of fracture of the mid-shaft of the radius.

Fractures of the Shafts of the Radius and Ulna Above the Level of the Interosseous Membrane

These fractures are rare, and there were only seven in this series. In all, union occurred with minimum displacement; and, once the fractures had united, there was no loss of supination or pronation. The absence of any limitation of rotation appears to be related to the absence of the interrosseous membrane at this level, although the fundamental factor probably is that at this level the movement of the radius is almost entirely a rotary one around its axis, which lies mainly within the shaft. The radius in its upper third, therefore, does not swing around the ulna; and fibrous tissue or callus formation around the ulna will not affect supination or pronation, unless it extends so far as actually to bind the radius and ulna together.

Fractures of Both Radius and Ulna

Limitation of rotation is due to the summation of the factors present in fractures of the radius and ulna, respectively. The triangular fibrocartilage often escapes damage in double fractures of the forearm, so that the fractured ulna is the main cause of limitation of rotation.

CASES IN WHICH ANGULATION OR DISPLACEMENT ADDS TO THE LIMITATION OF ROTATION

Lateral displacement is not very important, provided the alignment is good; but occasionally a considerable degree of lateral displacement of both bones may contribute to the development of cross union (Fig. 10-A).

Malalignment is a much more frequent cause of loss of rotation. The commonest error in reduction of a fracture of both bones of the forearm is failure to align the bones to their normal, anteriorly concave curve. Then, after union has occurred, there is an anterior projection of both bones when the forearm is in supination. In pronation, the radius rotates so that the abnormal projection now presses against the similar projection on the ulna, and hence marked limitation of pronation results. The same thing may occur in fractures of the radius alone, but of course the limitation of pronation is much more marked when both bones are angled.

Rotational Displacement of the Fragments in Fracture of the Shaft of the Radius: A pure rotation movement of either the upper or lower fragment of the radius does not occur. The fragments can only move in their normal arc around the ulna, although, in the case of the upper fragment, the purely rotary component is the main one. In the case of the lower fragment, the swinging bucket-handle movement is the major component. This being the case, it follows that, if there is a rotary displacement between the two fragments, the frag-

FIG. 10-A

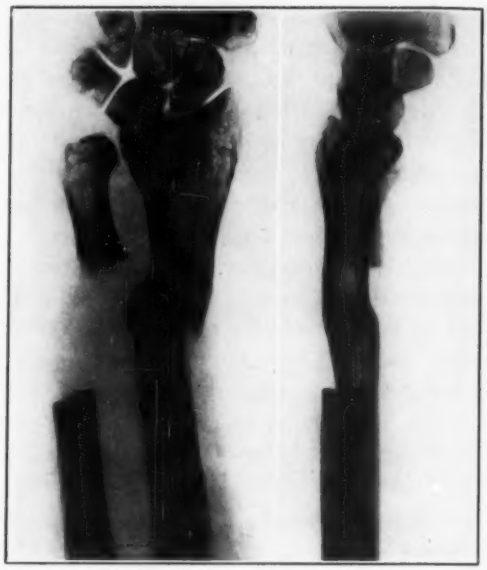

FIG. 10-B

Fig. 10-A: Roentgenograms show fracture in good alignment, but lateral displacement has almost resulted in cross union.
Fig. 10-B: Same patient, treated by Baldwin's operation.

ments will also be out of alignment. In practice, therefore, one has only to get the fragments of the radius in perfect alignment to be sure of correcting all rotary displacement. The old rule that in fractures above the insertion of the pronator teres the upper fragment is supinated by the biceps muscle, while fractures below this level have the upper fragment in a mid-position of rotation, appears to be generally correct. The only safe rule in reduction, however, is to place the forearm in such a degree of rotation that exact alignment is secured.

THE PREVENTION AND TREATMENT OF LOSS OF ROTATION

Children never seem to develop permanent loss of rotation, provided a reasonably good closed reduction of the fracture has been obtained. Therefore the following remarks need only be considered as applying to adults.

Fractures of the Head of the Radius

The treatment is largely prophylactic. All patients with fractures of the head of the radius should practise full passive rotation, as well as active rotation, from the day of injury. Apart from this, the orthodox treatment is carried out, the elbow being held in flexion by a collar-and-cuff sling.

As mentioned previously, it is the severe fractures, mainly those in which the whole head has had to be excised, in which marked limitation of rotation is apt to develop; and early rotation should be carried out regularly in such cases. In the past five years, thirty-two cases of fracture of the head of the radius have been treated by excision of the whole head, and, with only a few exceptions, the performance of supination and pronation from the day after operation has resulted in an almost complete return of rotation. There has also been a marked improvement in the final range of extension at the elbow; and in almost all cases a full range of all elbow movements has resulted. The explanation of the final full range of extension probably is that adhesions which form between the capsule and the raw bony surface of the radius are kept long and lax by the early rotation, and so do not limit extension. The general rule—namely, that forced flexion and extension of an injured elbow should be avoided—should probably be supplemented by the clause that active and passive

supination and pronation should be maintained from the day of injury, particularly in cases of fracture of the head of the radius. Even with early rotation, callus formation is singularly absent.

The exceptional results occurred in seven patients in whom a mass of callus developed on the anterior surface of the neck of the radius; severe restriction of rotation resulted, as well as considerable loss of extension (Fig. 7). All were cases of comminuted fracture of the head of the radius, associated with posterior dislocation of the elbow, in which excision of the head was carried out after closed reduction of the dislocation. Two of these patients performed no rotation exercises, while the others practised supination and pronation immediately after operation, but the final results were equally bad in all cases. The last two cases of fracture-dislocation were treated by closed reduction of the dislocation, followed by excision of the head five weeks later. This delayed excision of the head did not prevent the formation of a mass of callus, and the final results were no better than in those patients treated by immediate excision of the head. In four of the cases, the mass of callus was finally excised at a second operation about six months afterward, but improvement in function of the elbow joint was only moderate.

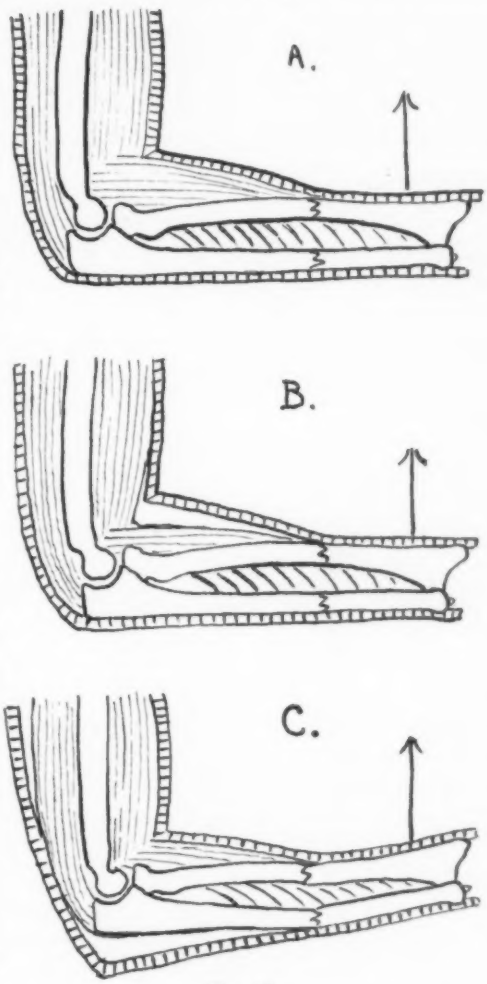

FIG. 11

Diagrams to illustrate how angulation of a fracture of the radius and ulna can occur in plaster. The arrow indicates where the plaster is supported by a sling.

Fractures of the Shafts of the Radius and Ulna

Open operation upon a fracture of the radius and ulna inevitably increases the soft-tissue damage and the reaction around the bone, and for this reason operation usually produces still further loss of rotation. Certain oblique fractures of the forearm bones, however, require internal fixation if displacement is to be avoided. As explained before, an excess of fibrous tissue or callus around a fracture of the radius will not affect rotation, apart from some inevitable loss of pronation; and so the author makes it a practice, whenever possible, to fix only the fracture of the radius. Usually, once the fracture of the radius has been well reduced and plated, the fracture of the ulna is found to be relatively stable; and further fixation of the forearm bones can be secured with plaster. Open manipulation of fracture of the ulna may result in an increase in callus and fibrous tissue around the fracture; and, unless absolutely necessary, operation upon the ulna should be avoided.

One of the complications frequently encountered in dealing with forearm fractures is the angulation which often develops while the well-set fractures of the radius and ulna are held in an unpadded plaster. The explanation of this apparently anomalous development of deformity is simple. When the forearm is first set and fixed, the plaster fits the contours of the arm closely (Fig. 11, *A*). Much of the weight of the plaster is taken by the collar-and-cuff sling tied around the wrist, but the brachioradialis muscle also supports a good

deal of the weight. This muscle, however, which acts only upon the elbow joint, has no opportunity of contracting so long as the elbow is immobilized; the muscle therefore atrophies rapidly, and a space forms beneath the plaster, over the upper surface of the proximal half of the forearm (Fig. 11, *B*). The plaster cast then sags here and, as the distal fragments of the forearm bones are still firmly held—since they are surrounded mainly by tendons—angulation occurs (Fig. 11, *C*). The method of preventing this angulation is to incorporate a calico bandage in the last layer of plaster at a point just below the elbow joint; the calico bandage fixed at this level is the only suspension allowed. The author has employed this form of suspension in all cases of forearm fracture for the last three years, and has had no cases of angulation occurring under plaster during this time. The present universal method of suspending plasters for forearm fractures by means of collar-and-cuff slings should be completely abandoned.

Cross Union

Open operation on the radius and ulna is the commonest cause of cross union, and it is probable that at such operations the fault lies in unnecessary exposure of the interosseous aspect of the bones, as when the ends of the bones are made to extrude through the wound. Such a procedure is particularly apt to be followed by cross union in children, but fortunately successful closed manipulative reduction can almost always be done at this age.

Complete bony cross union is rare, although a lesser degree of callus formation is more often encountered. Even without complete bony fusion, the rotation movement may be almost lost.

Once cross union has become established, or a condition close to this has developed, what can be done? The cases most easily treated are those in which the cross union is in the lower third of the forearm. There the treatment simply consists in excision of one inch of the ulna, with its periosteum, at the site of the fracture, as well as the mass of callus between the bones (Baldwin's operation) (Fig. 10-B). A full range of supination and pronation is obtained, although there is sometimes slight loss of gripping power.

Where cross union has occurred in the middle third of the forearm bones—and this is the commonest site—treatment is much more difficult. The surgical treatment of such a condition at this level is to excise one and one-half inches of the ulna, with the adjacent mass of callus and the surrounding periosteum. The mass of flexor and extensor muscles is then carefully sutured together to obliterate any dead space, and the wound is closed. After a three-month interval, when roentgenograms show no new callus formation, a whole-thickness fibular graft is inserted across the gap. Two patients have been treated by this method, and in each case a 75 per cent. range of rotation was regained.

The rationale of this treatment can be understood by considering Figures 8, *A* and 8, *B*. Obviously, it is the mass of callus around the ulna which must be removed. The operation, if performed successfully, produces a condition in which the remaining callus around the radius leaves rotation quite unaffected, provided a supple membranous scar takes the place of the mass of callus around the ulna.

Colles's Fracture

It is unusual for a severe permanent limitation of rotation to develop in a patient with Colles's fracture, but sometimes this does occur and demands treatment. Forced passive movements and other forms of physiotherapy seem to have little effect, and forced manipulation under anaesthesia usually causes a spiral fracture of the lower third of the ulna.

Excision of the head and neck of the ulna, with its periosteum, has proved an easy and reliable way to recover full rotation in such cases. The bone is exposed through a posteromedial incision, and the dissection is done extraperiosteally with a scalpel. The ulna is divided one inch above the wrist joint with bone shears, and the head of the ulna is dissected off the adherent triangular fibrocartilage, starting from the radial side. The triangular fibrocartilage and the ununited ulnar styloid are left *in situ*, so that the wrist joint is not

opened. The removal of the periosteum ensures the absence of any new-bone formation. Both active and passive rotation are practised from the day after operation. The immediate result is an increase in the limitation of supination and pronation, which may persist for as long as six weeks. Thereafter a full range of supination and pronation rapidly develops. The results of this operation are particularly gratifying to those patients in whom impaction of the fracture and an ugly projecting ulnar head had been present, as well as the loss of rotation. After the postoperative swelling has subsided, the appearance of the wrist is only slightly different from normal. The tendon of the extensor carpi ulnaris prevents the appearance of a hollow.

Twenty-four such operations have been done in the past four years,—nearly all in females. Twenty of the patients were discharged without any complaint of disability and with full supination and pronation. The other four patients either had slight limitation of rotation, or had a sense of weakness in the wrist during such actions as carrying a shovelful of coal or lifting down a heavy pot from a shelf; but even in these cases the return of rotation was well worth the slight weakness which ensued.

LOSS OF ROTATION DUE TO CAUSES OTHER THAN FRACTURES

Volkmann's Contracture

In this condition the flexor muscles are replaced by a mass of fibrous tissue. As this fibrous tissue contracts, the forearm is pulled into pronation and all power of supination is lost. Little attention seems to have been paid to this pronation deformity, and in severe cases of Volkmann's contracture it is of little importance. In the mild cases, however, physiotherapy should be directed toward preventing this permanent pronation deformity, as well as toward stretching the flexor tendons.

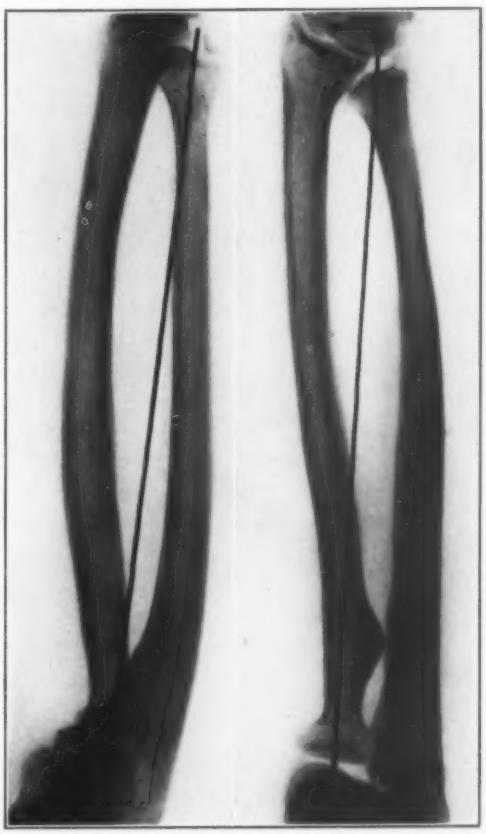

FIG. 12-A

Roentgenograms of forearm bones in patient with spastic paralysis of the right arm, present since birth. Supination was almost lost (see Fig. 12-B). Note how the axis of rotation of the radius deviates from the line of the interosseous ridge of the ulna.

Loss of Rotation in Paralytic and Spastic States

In Erb's paralysis, supination of the forearm is lost to a certain extent. When a patient is seen several years after the birth injury, one may find that the degree of residual paralysis is only slight; and certainly the power of the biceps often appears ample to effect supination. The cause of the loss of supination is to be found in a study of the curvature of the ulna. In infancy, the child, finding supination difficult, does not perform this movement; and so the traction effect of the interosseous membrane, in causing the interosseous edge of the ulna to mold itself along the axis of rotation of the radius (Fig. 2), is absent. The ulna becomes curved, so that its interosseous border lies in front of the axis of rotation of the radius. In later years, when supination is attempted, the position of the interosseous border of the ulna in relation to the axis of rotation of the radius results in the membrane becoming taut, and in this way supination is permanently restricted.

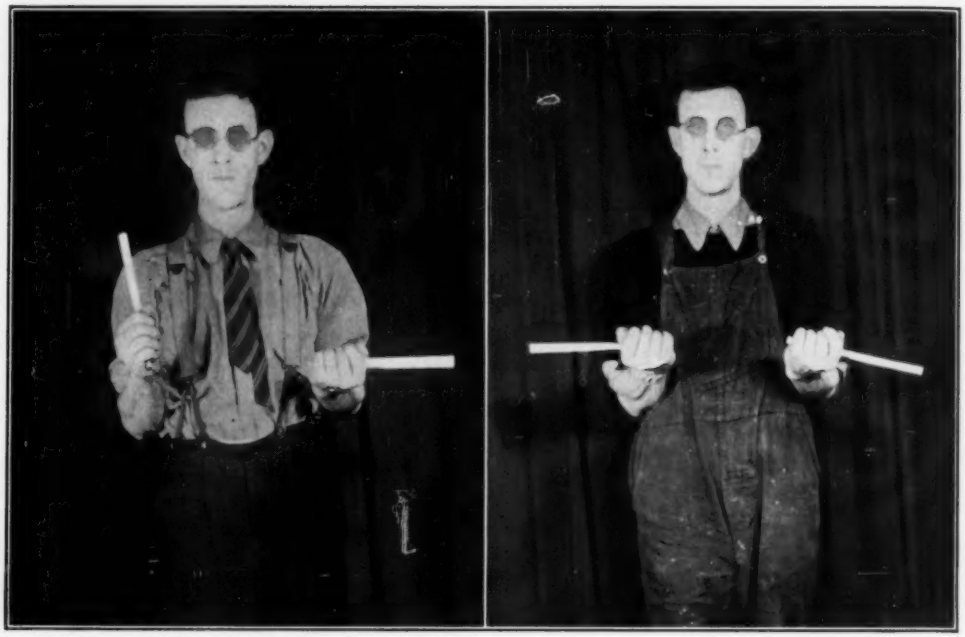

FIG. 12-B FIG. 12-C

Fig. 12-B: Patient with mild spastic paralysis of right arm and loss of supination since birth.
Fig. 12-C: Range of supination six months after excision of the head of the ulna.

A similar alteration in the curvature of the shaft of the ulna may develop in cases of mild spastic paralysis of the upper limb (Fig. 12-A) or in infantile paralysis; and in later years this abnormal ulnar curvature will prevent successful cooperative attempts at rotation.

When the rotator muscles of the forearm are strong and controlled, considerable improvement in the range of rotation can be obtained by performing an osteotomy of the upper third of the ulna, and realigning the shaft so that the interosseous border conforms to the axis of rotation of the radius. This realignment is obtained simply by forcing the forearm into full supination or pronation after osteotomy, and fixing it in plaster until union is sound; the interosseous membrane thereby pulls the ulna into the necessary alignment.

The author has done this only twice; others, including Blount[1], have done it frequently, but they have been under the impression that a rotation osteotomy of the ulna had been done. A study of the roentgenograms, however, shows that, whether or not rotation of the ulna was effected, a very good realignment of the interosseous border of the ulna along the axis of rotation of the radius was made; the improved rotation was unwittingly caused by the realignment of the ulna, and was not due to rotation osteotomy.

In the past, limitation of supination has frequently been ascribed to spasm or contracture of the pronator teres; and tenotomy of that muscle has often been done without any obvious improvement in the supination range. An alternative to osteotomy and realignment of the ulna in such cases is to excise the head and neck of the ulna. When this has been done, the ulna can swing toward the radius when the interosseous membrane tends to tighten; and so the main factor limiting supination is abolished and an increased range of supination results. Two cases of spastic hemiplegia, present since birth, have been treated in this way; and in both an almost full range of rotation has resulted (Figs. 12-B and 12-C).

1. BLOUNT, W. P.: Osteoclasis for Supination Deformities in Children. J. Bone and Joint Surg., **22**: 300–314, Apr. 1940.

END RESULTS OF BONE-GRAFTING FOR NON-UNION OF THE CARPAL NAVICULAR *

BY GORDON MURRAY, M.D., TORONTO, ONTARIO, CANADA

It is now sixteen years since the first bone-grafting of the carpal navicular by this particular method[1] was carried out. The purpose of this presentation is to report the results of 100 such bone grafts for non-union of fractures of the navicular.

A further report on this procedure was thought advisable for two reasons:

1. The procedure has given excellent results, with good function of the wrist, in the vast majority of cases.

2. During World War II there have been several reports, especially from the Canadian military surgeons, on the results of bone-grafting; in most instances the reports were not favorable. After reading these reports and talking with several of the surgeons, the author believes that there are reasons why the results of these operations were not satisfactory.

In the first place, many of the operations were performed by men who had not seen the procedure carried out, and who were doing the operation for the first time. The operations were done by different operators, and many of the surgeons had not done more than one or two of the total series reported.

The second factor which may contribute to a failure is that an insufficiently large graft has been used. In one case not reported in this series, another operator had done a bone graft; he placed the graft in good position, but used a small piece of bone,—smaller than the size of a match.

From experience with the operation, the author believes that certain principles must be followed to obtain the best results.

1. The bone graft must be large. In other words, the drill which makes the hole must cut away a large proportion of the face of the fracture surface in both fragments. When this has been done and a large graft has been inserted to take its place, the surrounding bone becomes calcified and ossified and the union is satisfactory.

2. The graft must be well placed so that it goes through the distal fragment, across the fracture line, and well into the proximal fragment, so that there is no doubt regarding the contact of the graft with the proximal fragment.

3. The drill hole must not be so large that it cuts through the articular cartilage and bursts into any of the surrounding articulations.

4. After the bone graft has been placed in position, the final procedure must be to drive the distal fragment down firmly so that it is impacted against the proximal fragment; the graft must fit tightly enough to hold the fragments firmly in apposition.

5. There must be adequate splinting of the wrist, including all metacarpals and the proximal phalanges, or probably both phalanges of the thumb, so that the wrist and the first metacarpal are completely immobilized. This should be continued for a minimum of ten weeks and, where there is devitalization of the proximal fragment, for a much longer period. This time can be determined by the roentgenographic appearance of revascularization of the proximal fragment.

6. Splinting must be continued until there is roentgenographic evidence of union of the fracture. The graft must be united to both fragments, and the fracture line surrounding the graft must show trabeculae crossing it.

The question arises of whether cortical bone from the tibia, or cancellous bone from the ilium or elsewhere, should be used. In all the cases in this series, cortical bone—usually from the tibia—has been used, for the following reasons:

* Presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 28, 1946.

FIG. 1-A FIG. 1-B FIG. 1-C

Fig. 1-A: J. K., Case 11. Shows non-union of a fracture through the waist of the navicular of one year's duration. Some arthritic changes are present in the wrist joint, as indicated by an elongation of the styloid process of the radius. In spite of this, bone-grafting was undertaken.

Fig. 1-B: Shows the graft in position, with beginning union of the graft to both fragments and union of the fracture.

Fig. 1-C: Shows the result after four years. The arthritic changes have not increased. The graft has united solidly. The fracture line has disappeared and the end result is good. This patient has an excellent range of motion; the functional result is estimated at 88 per cent.

1. The strong, heavy bone can be chiseled into the proper shape, and it can be driven in firmly and handled without breaking into pieces.

2. It maintains its strength, even with firm impaction of the fragments.

3. In this series of cases, the bone has proved sufficiently osteogenic to do its work. While cancellous bone may have better properties in this respect, still the results here justify the procedure. Cancellous bone might effect an earlier union of the fracture, but the stability and other qualities of the cortical bone produce results which are difficult to obtain with the cancellous bone.

FIG. 2-A FIG. 2-B

Fig. 2-A: K. L., Case 21. Shows ununited fracture of navicular of seven months' duration. There is aseptic necrosis of the proximal fragment, but no arthritic or degenerative changes are present in the wrist joint.

Fig. 2-B: Shows the result six months after bone-grafting. The fracture has united, and the graft has united to both fragments. The proximal fragment still shows aseptic necrosis, as does the adjacent lunate bone. Revascularization of the proximal fragment can be expected to occur as the months pass.

RESULTS

Out of 100 cases included in this report, bony union occurred in ninety-six, and the function in all of these was very satisfactory. In some patients the range of motion was 100 per cent. in all directions, without any disability or discomfort. In some of the others,

FIG. 3-A

FIG. 3-B

Fig. 3-A: F. D. Case 43. Shows a mid-carpal dislocation, with fracture of the navicular.

Fig. 3-B: Open reduction has been performed. Roentgenogram shows a good reposition of the dislocated carpal bones, with a bone graft in the navicular. The proximal fragment of the navicular shows marked aseptic necrosis.

FIG. 3-C

FIG. 3-D

Fig. 3-C: Shows beginning union of fracture after operation, with the graft united to both fragments. The proximal fragment, however, shows markedly increased density, indicating aseptic necrosis.

Fig. 3-D: End result after bone graft for dislocation of mid-carpal joint, thirteen years after the operation for reduction. The navicular has united solidly. The area of aseptic necrosis in the proximal fragment has become completely revascularized. No arthritic changes are present in the joint. The patient has an excellent range of motion; he has returned to heavy laboring work and has continued at it for thirteen years.

TABLE I

DATA ON 100 CASES OF BONE-GRAFTING FOR NON-UNION OF THE CARPAL NAVICULAR *

No.	Patient	Age	Duration of Fracture Before Operation	Previous Treatment	Time Since Operation (*Years*)	Duration of Fixation After Operation	Time Between Operation and Return to Work (*Months*)	Union	Degree of Function (*Per cent.*)	Remarks
1	B.S.	31	6 mos.	Missed	16	12 wks.	4½	Yes	98	
2	F.S.	20	3½ mos.	Missed	15	12 wks.	3½	Yes	—	
3	W.M.	28	2½ mos.	Missed	15	12 wks.	5	Yes	95	
4	M.S.	30	4 mos.	Missed	14	13 wks.	5½	Yes	95	
5	G.H.	21	3 mos.	Missed	14	Few days	3 wks.	No	—	
6	K.G.	23	14 mos.	Missed	9	12 wks.	7	Yes	75	
7	G.G.	42	2 yrs.	Missed	8	14 wks.	8	Yes	80	
8	E.R.	38	6 mos.	Plaster, 6 wks.	4	12½ wks.	5½	Yes	90	
9	N.B.	28	2½ yrs.	None	4	14 wks.	8	Yes	75	
10	C.R.	30	6 mos.	None	3	12½ wks.	6½	Yes	85	
11	J.K.	28	1 yr.	None	4	13 wks.	7½	Yes	88	
12	R.A.	31	5 mos.	Plaster, 2 mos.	3	32 wks.	9½	Yes	75	Aseptic necrosis, proximal fragment.
13	T.M.	38	8 wks.	Plaster, 8 wks.	3	16½ wks.	8½	Yes	68	Mid-carpal dislocation and fractured navicular.
14	A.W.	32	Previous non-union	Bone graft by Dr.H.M.	3	20 wks.	6½	Yes	72	Previous bone graft for non-union.
15	J.G.	26	2½ yrs.	Plaster, 8 wks.	3	11 wks.	3¾	Yes	93	Some cystic changes in both fragments.
16	A.H.	41	6 mos.	Plaster	2	12 wks.	4	Yes	95	
17	R.J.	38	1½ yrs.	Missed	2	16 wks.	5	Yes	88	
18	M.B.	40	2 mos.	Plaster, 2 mos.	2½	12 wks.	5	Yes	90	Severely comminuted fracture.
19	F.C.	32	5 mos.	Missed	2	13 wks.	5½	Yes	88	Aseptic necrosis, proximal fragment.
20	H.J.C.	29	5 mos.	None	2	14 wks.	5	Yes	92	
21	K.L.	19	7 mos.	Plaster, 2 mos.	2	16 wks.	6	Yes	80	Aseptic necrosis of lunate bone.
22	A.B.	46	4 yrs.	None	2	20 wks.	—	No	—	Aseptic necrosis, proximal fragment. Other arm missing.
23	C.R.	20	1 yr.	None	2	12 wks.	4½	Yes	96	
24	J.P.	19	1½ yrs.	Missed	1½	13 wks.	6½	Yes	95	
25	Dr.K.	42	10 yrs.	None	1½	14 wks.	6½	Yes	65	Moderate arthritis present.
26	H.S.	32	2 yrs.	Splints	1	4 mos.	9	Yes	94	Aseptic necrosis of proximal fragment; revascularized.
27	J.B.	26	1½ yrs.	Splints	2	6 mos.	13	No	—	Aseptic necrosis of both fragments; finally fusion of wrist.
28	W.P.	31	3 yrs.	Missed	3	5 mos.	7	Yes	82	Moderate cystic degeneration.
29	R.S.	17	3 wks.	Splints	1	4 mos.	6	Yes	75	Mid-carpal dislocation also.
30	A.B.	22	4 mos.	Missed	1	4 mos.	7	Yes	90	Plus fracture, head of radius.
31	C.R.	25	5 yrs.	None	1½	4½ mos.	7½	Yes	84	Moderate aseptic necrosis, proximal fragment.
32	A.B.	32	5 mos.	Splints	9	3 mos.	4	Yes	97	
33	B.H.	19	1½ yrs.	Splints	8	11 wks.	3½	Yes	99	
34	G.F.	21	4 mos.	None	6	3 mos.	4½	Yes	99	
35	T.G.	18	4½ mos.	None	8	3½ mos.	5	Yes	96	
36	M.G.	22	3½ mos.	None	12	3 mos.	4½	Yes	98	
37	L.L.	28	6 mos.	Missed	12	3½ mos.	5	Yes	95	
38	G.L.	21	3 mos.	Missed	11	3 mos.	4	Yes	98	
39	S.R.	26	6 mos.	None	11	3 mos.	4½	Yes	92	
40	N.S.	28	7 mos.	None	10	3½ mos.	5½	Yes	92	
41	G.E.	27	10 mos.	Splints	9	4 mos.	6½	Yes	94	

* With the exception of Case 9, all the patients in this series were males.

TABLE I (*Continued*)

No.	Patient	Age	Duration of Fracture Before Operation	Previous Treatment	Time Since Operation (*Years*)	Duration of Fixation After Operation	Time Between Operation and Return to Work (*Months*)	Union	Degree of Function (*Per cent.*)	Remarks
42	M.I.	38	3 mos.	None	7	3 mos.	5	Yes	96	
43	F.D.	32	1 mo.	Splints	13	4 mos.	9	Yes	90	Mid-carpal dislocation and aseptic necrosis.
44	G.M.	36	6 mos.	None	7	5 mos.	8	Yes	81	Aseptic necrosis, proximal fragment.
45	J.G.	30	3½ mos.	None	11	8 wks.	3	Yes	97	
46	A.M.	22	4 mos.	None	9	10 wks.	4	Yes	98	
47	H.K.	35	6 mos.	Splints	9	3 mos.	5½	Yes	90	
48	T.T.	28	5 mos.	None	6	3 mos.	4½	Yes	92	
49	A.T.	41	4½ mos.	None	9	3½ mos.	6	Yes	93	
50	H.T.	50	4 mos.	None	10	3½ mos.	5	Yes	90	
51	H.F.	17	3 mos.	Splints	8	3 mos.	4½	Yes	97	
52	J.F.	26	4 mos.	Splints	9	3½ mos.	5	Yes	92	
53	F.A.	24	5 mos.	None	8	3 mos.	5	Yes	96	
54	F.J.	42	3 mos.	None	7	3½ mos.	5	Yes	92	
55	S.B.	39	8 mos.	Missed	11	4 mos.	5½	Yes	87	
56	G.F.	41	3½ mos.	None	9	3 mos.	4½	Yes	92	
57	L.R.	21	6 mos.	None	5	3 mos.	6	Yes	80	
58	M.G.	19	4 mos.	None	11	2½ mos.	4	Yes	98	
59	A.G.	39	11 mos.	None	6	5 mos.	5	Yes	92	
60	P.R.	31	6 mos.	None	12	3 mos.	5	Yes	94	
61	G.D.	24	7 mos.	Splints	4	3½ mos.	4½	Yes	90	
62	I.L.	25	3 mos.	Splints	5	3 mos.	5	Yes	94	
63	S.M.	29	13 mos.	Splints	7	4½ mos.	6	Yes	84	Aseptic necrosis, proximal fragment.
64	M.H.	39	2½ mos.	None	8	3 mos.	4	Yes	98	
65	L.C.	46	4 mos.	Splints	9	3 mos.	4½	Yes	94	Aseptic necrosis, proximal fragment.
66	G.C.	35	2 yrs.	None	7	3½ mos.	6	Yes	94	
67	A.B.	29	4 mos.	None	10	3 mos.	4½	Yes	95	
68	A.M.	42	6 mos.	None	11	3 mos.	5	Yes	96	
69	L.C.	41	7 mos.	Splints	10	3½ mos.	4½	Yes	89	
70	M.J.	30	3 mos.	Splints	12	3 mos.	5	Yes	94	
71	S.F.	20	1 yr.	None	6	3 mos.	5	Yes	90	Aseptic necrosis.
72	K.B.	34	6 mos.	None	8	3½ mos.	6	Yes and no	97	Non-union; regrafted and united.
73	J.H.	18	3 mos.	None	11	3 mos.	4½	Yes	99	
74	C.M.	40	1 yr.	None	6	4 mos.	6	Yes	90	
75	R.M.	28	4 mos.	None	5	3 mos.	4½	Yes	94	
76	A.W.	34	3 mos.	Bone-grafting	5	8½ mos.	6	Yes	90	Previous bone graft failed.
77	L.S.	50	6 mos.	Splints	5	3 mos.	6½	Yes	88	
78	G.A.	21	3 mos.	None	10	3½ mos.	6	Yes	91	
79	F.A.	32	4 mos.	None	4	2½ mos.	4	Yes	95	
80	L.B.	40	5 mos.	None	6	3 mos.	4	Yes	98	
81	E.S.	29	8 mos.	Missed	9	3½ mos.	5½	Yes	95	
82	M.L.	31	4 mos.	None	11	3 mos.	4½	Yes	92	
83	A.N.	35	7 mos.	None	7	3½ mos.	5	Yes	94	
84	A.W.	38	5 mos.	None	11	3 mos.	6	Yes	95	Aseptic necrosis.
85	N.D.	41	9 mos.	None	13	4 mos.	6	Yes	91	Aseptic necrosis.
86	D.H.	24	11 mos.	None	4	3½ mos.	5½	Yes	89	
87	F.D.	29	3 mos.	None	5	3 mos.	6	Yes	92	Aseptic necrosis.
88	S.E.	40	4 mos.	None	11	3½ mos.	4½	Yes	94	
89	M.G.	28	8 mos.	None	6	3 mos.	5	Yes	95	
90	A.K.	31	3 mos.	None	7	3 mos.	4½	Yes	94	
91	F.L.	34	4 mos.	None	6	3 mos.	5	Yes	96	
92	J.O.	42	5 mos.	Missed	7	3 mos.	4	Yes	92	
93	M.O.	22	3 mos.	Missed	3	3 mos.	4	Yes	98	
94	J.A.	29	2 yrs.	Missed	3	4 mos.	6	Yes	92	
95	O.S.	46	1 yr.	Missed	4	3½ mos.	5½	Yes	94	
96	J.B.	36	1 mo.	Splints	6	3½ mos.	7	Yes	86	Mid-carpal dislocation.
97	M.P.	26	4 mos.	Splints	4	3 mos.	4	Yes	94	
98	J.M.	25	5 mos.	None	6	3 mos.	4½	Yes	95	
99	F.N.	20	3 mos.	None	7	3 mos.	4	Yes	95	
100	J.N.	39	15 mos.	Splints	7	4 mos.	5½	Yes	92	

FIG. 4-A

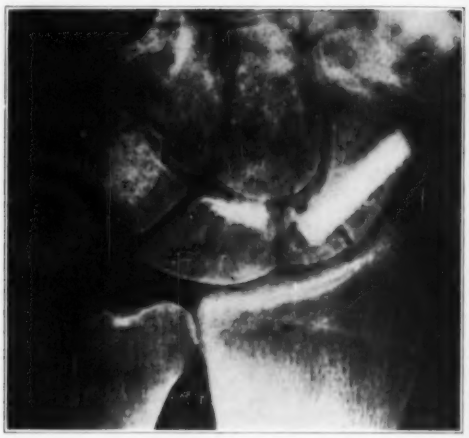

FIG. 4-B

Fig. 4-A: F. S., Case 2. Ununited fracture at the junction of the proximal and middle thirds of the navicular.
Fig. 4-B: Bone graft in position after operation.

FIG. 4-C

FIG. 4-D

Fig. 4-C: Shows union of the fracture.
Fig. 4-D: Roentgenogram of end result, sixteen years after bone-grafting, shows solid union of the fracture. The graft is still visible. The bone is viable throughout. There is no arthritis in the wrist joint and no degenerative change as a result of either the fracture or the bone-grafting.

where there had been prolonged non-union and where a doubtful amount of arthritis was present in the wrist, the range of motion did not return to normal. However, the range of motion was useful and painless, and was sufficient so that the patients were able to return to their original work without discomfort or disability.

Of the four cases of non-union, one occurred in a boy of not very high intelligence, who removed his plaster and went back to heavy work using his wrist within three weeks of his operation. He reported a year later, with the graft fractured and complete non-union of his navicular. Roentgenograms of this patient's wrist could not be obtained.

The next case of non-union was in a patient in whom the graft had not been placed sufficiently far across the fracture line and into the proximal fragment to provide the conditions already enumerated. This resulted in non-union. The patient was operated upon at a later date, another graft was placed across this area, and solid union occurred with a good functional result in the wrist.

The third patient had had an amputation of one arm, and had a fracture with non-

union of the navicular in his remaining arm. Unfortunately, fairly marked arthritis was present in the wrist joint. Aseptic necrosis of the proximal fragment, with marked cystic degeneration, extended widely from the fracture surfaces of both fragments. Under ordinary circumstances, this bone would be considered unsuitable for grafting. Since the patient had only one hand, however, it was thought that an attempt should be made to improve the function of his wrist. For that reason, the operation was undertaken. Eventually non-union resulted. It is possible that, throughout his convalescence, the patient used this hand for all the necessary functions of life, and his thumb and the remainder of his hand and wrist may not have been given the necessary rest period for solidification of the fracture. Ultimately the navicular was excised, because of the pain and disability in the wrist.

The fourth patient had lack of apposition of the fragments.

The contra-indications for operation for non-union of the navicular are as follows:

1. Practically all early fractures, if splinted adequately, will unite, so that bone-grafting for recent fractures is not a necessity.

2. In fractures in which the non-union has existed for such a length of time that there is arthritis in the wrist, disappearance of the articular cartilage between the navicular and the radius, or elongation of the styloid process of the radius, grafting should not be done because, even though the bone should unite solidly, the disability due to the arthritis in the wrist will not be corrected.

The presence of aseptic necrosis of the proximal fragment is not a contra-indication, but is an absolute indication, for bone-grafting, provided generalized arthritic changes are not present in the wrist. With grafting, the devitalized fragment becomes revascularized and the fracture unites in most cases.

One essential reason for doing a bone graft in non-union of fracture of the navicular is that, if the non-union continues for a long period of time, arthritis of the wrist joint develops. This is a bad permanent disability which, when it has reached a late stage, can be overcome and the disability lessened only by an arthrodesis of the wrist. The fact that there are people with non-union of the navicular who say that they have no disability and that they use their wrists actively is no proof that, as further time elapses, arthritis will not develop in the wrist, with consequent disability. The fact that these fractures will unite, and that the navicular bones will remain healthy and continue to function for as long as sixteen years, is adequate evidence that this is a good standard procedure; and, if the rules are followed carefully, good results can be expected.

CONCLUSIONS

1. Of 100 cases of bone-grafting for non-union of the carpal navicular, bony union was obtained in ninety-six. The functional results were excellent.

2. The grafted navicular had a healthy appearance by roentgenogram as long as sixteen years after the operation.

1. Murray, Gordon: Bone-Graft for Non-Union of the Carpal Scaphoid. British J. Surg., 22: 63–68, 1934–35.

DISCUSSION

Dr. Robert I. Harris, Toronto, Ontario, Canada: As a colleague and friend of Gordon Murray, and one who has been intimately associated with him in fracture work in the General Hospital, I have followed with interest the inception and development of his idea of treating non-union of the carpal navicular by bone-grafting. Perhaps the most suitable contribution I can make to this discussion is to state that the operation is of value and the results are good.

I should like to emphasize a point which Dr. Murray made, — namely, that it is necessary to exercise selection in the cases in which bone-grafting is to be undertaken. If displacement of the fragments is of long standing and if there are arthritic changes, the results will not be entirely satisfactory even though union is secured, because the patient is still left with an osteo-arthritis, resulting from the fracture into

the articular surface. Irregularity of the articular surface remains, and this will produce disability in spite of union of the fragments.

An interesting and valuable item in the improvement in our management of fractures of the carpal navicular, which has come from Dr. Murray's contribution, has been the attention we now pay to the fresh fracture. The value of this has been accentuated by the experience gained in the Canadian Army, where facilities existed for developing a policy in the management of injuries to the wrist, influenced by a knowledge of fracture of the carpal navicular. It was easy to demonstrate, as I know it has been in the American Army, that this is a common fracture in the young male, and that it is frequently overlooked and misdiagnosed as a sprain. Only if we appreciate that this is a common fracture, which may not present obvious evidence of fracture, will we be alert and insist upon the use of roentgenograms for injuries of the wrist.

A word as to the management of the late cases which are still painful because of osteo-arthritis: In my experience, arthrodesis of the wrist joint gives the best result, particularly if the patient has to use his hand for heavy work.

Dr. Edwin F. Cave, Boston, Massachusetts: I am very glad indeed to have heard Dr. Murray read his paper on bone grafts for non-union of the carpal navicular. He has just reminded me that he read a paper before this Association on the same subject, twelve years ago. At that time he had a much smaller group of cases, but now I feel quite certain that his series is larger than any which has been followed with end-result studies.

I am a firm believer in the operation; but feel, as does Dr. Murray, that our cases should be selected carefully. Certainly the graft should not be introduced if there is arthritis to any degree, because, even though union of the fragments might be produced, symptoms in the wrist will continue. Also, I doubt the wisdom of attempting to graft in cases of fracture with a very small proximal fragment, which appears dead by roentgenogram. Possibly this type of case would be treated best either by excision of the small proximal fragment, or by grafting the navicular to the lunate bone. Grafting the carpal navicular is not an easy procedure, and it should not be undertaken by a surgeon who does not have a thorough knowledge of the anatomy of the carpus. He should be able to interpret roentgenograms of the carpus taken in various positions,—namely, anteroposterior in ulnar deviation, anteroposterior with the fist closed, oblique views, and lateral views. Roentgenograms of the normal wrist should always be taken for comparison. It is generally agreed that, if fractures of the navicular are diagnosed and treated early with prolonged immobilization, union can be expected in a high percentage of the cases. If at the end of four months, however, there is not evidence of bony union by roentgenogram, then I believe that the graft should be undertaken. Also, in cases which have not been diagnosed early and which have been neglected, grafting should probably be done, rather than immobilizing without the graft.

A few words about the technique of the operation: We have used the curved radial approach, and have inserted the drill and graft under roentgenographic control. We do not use the fluoroscope. To date we have used the tibia as the source of the graft and have removed the graft with the motor saw, taking the full thickness of the cortex, approximately three-eighths of an inch wide and four and one-half inches long. The end of this graft can be shaped to the proper size, and it can be held by the larger end as it is inserted into the navicular. Finally, it is cut off with a rongeur.

Dr. Murray is to be congratulated on his excellent operative results in a large series of cases. I doubt if anyone else can report 96 per cent. of bony union.

AN OPERATION FOR NON-UNION OF FRACTURES OF THE CARPAL NAVICULAR

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From the relative increase in the number of discussions on fractures of the carpal navicular reported in the literature, it may readily be presumed that there is an increase in the frequency of recognition of this fracture. This is predominantly borne out in military life, where one is apt to find a direct reversal of the usual ratio of ten Colles's fractures to one navicular fracture. This has been explained on the basis that an active young man has a strong supporting musculature, which prevents hyperextension of the wrist. The mechanism of this fracture can be justified on the following hypothesis: When hyperextension is prevented, the force is transmitted upward from the palm of the hand; the navicular is then jammed between the capitate bone and the radius. This force on the carpal navicular is one of compression and torsion at the waist. The concave surface of the navicular receives the capitate bone like a wedge, and this wedge action breaks the navicular when exerted at its point of maximum concavity, which is at the waist.

Snodgrass has presented an important physio-anatomical solution to this problem by outlining the following three causes for frequency of fracture of the carpal navicular: ". . . first, it is thinnest in its middle; secondly, the cortex, which is the only hard bone found in any of the carpals (the interior being cancellous), is perforated by small vessels in this area; and thirdly, the scaphoid is the largest and longest bone in the proximal row, and is not segmented, and therefore is less able than the osseous elements on the ulnar side of the wrist to withstand a fracturing force". As a fourth factor, the mechanism of hyperextension must be added. The fact that the navicular forms part of both the distal and proximal carpal rows, plus many other unknown mechanisms of force, may add to the frequency of the fracture in military service. Fractures of the tubercle are extra-articular in relation to the carpus and are of the avulsion type, caused by excessive stress placed upon the radial collateral ligament, which is attached to it.

Properly regulated methods of recognition and immobilization of fresh fractures, or peg-grafting for non-union, will usually produce union. Many fractures of the navicular are not found at first examination, due either to faulty roentgenographic technique, which fails to show a hairline type of fracture, or to the fact that the fracture line itself is not visible. However, the fracture may be seen within ten days to two weeks after the initial injury, with a check roentgenogram. This delayed appearance of the fracture line is explained on the basis of a lowered pH in the local tissue fluid. When there is a relative increase in the hydrogen-ion concentration, the solubility of the calcium salts is increased, resulting in absorption of calcium salts at the fracture site with a subsequent widening of the fracture line[2]. The fracture then becomes visible on the roentgenogram. All sprained wrists should be considered fractures of the carpal navicular until proved otherwise. Clinically the diagnosis may be suggested by a history of a fall on the hyperextended palm, by tenderness in the anatomical or king's snuffbox, by limitation of flexion, and by aggravation of the pain with ulnar deviation. The absolute diagnosis is based purely upon roentgenographic evidence.

METHODS OF TREATMENT

The medical literature indicates a progressive change in the treatment of these fractures. At first a cock-up splint was applied for ten days, followed by massage and electrotherapy for four or five days. Motion was then started; and if after four or five weeks no union had occurred, the carpal navicular was removed. Since then the treatment has

consisted either of resection of one or both fragments, of the proximal row of carpal bones with the proximal fragment, or of the entire navicular; arthrodesis of the joint; and, more recently, immobilization in plaster-of-Paris for as long as twenty-four months. Efforts to obtain bony union surgically have included the use of onlay grafts, multiple drilling of the fragments, a single large peg graft, and, finally, the present method of multiple peg grafts. The authors feel that the prolonged use of plaster-of-Paris casts not only involves some occupational and economic interference, but also produces decalcification and osteoporosis of the bones of the forearm, wrist, and hand; this is more than a simple disuse atrophy, as suggested by Watson-Jones and Roberts.

The shortest period of immobilization which is commensurate with bony union would seem to be the treatment of choice. Although it is sometimes difficult to evaluate symptoms, the authors believe that ununited fractures are painful. The period of immobilization need not be unduly long, if the fractures are recognized early and are adequately immobilized. The authors had used for years the method which Thorndike and Garrey described in 1940 and called the "standard" method of immobilization of fresh fractures. The wrist is immobilized by a cast in 50 degrees of extension and slight radial deviation, with the thumb included in the cast to the interphalangeal joint. To this may be added the necessity of firmly locking the fragments by wide abduction of the thumb, which increases the radial deviation. This method is similar to the one advocated by Ritter.

It has been the authors' policy to immobilize the fracture by the method outlined for a period of six weeks. At the end of this time the cast is removed, and a roentgenogram is taken. If trabeculation across the fracture site is not complete, another cast is applied for two weeks. By the end of this time, union usually has taken place. Operative procedures are not considered until a full trial of immobilization has been given. If the fracture has not healed at the end of the eight-week period, the immobilization is continued for a total of twelve weeks.

Bone-grafting has been done only on those patients who had fresh fractures which did not heal. No fracture was considered amenable to grafting which was older than one year. The criteria of non-union are based upon roentgenographic findings alone. Roentgenographic evidence of non-union consists of sclerosis and eburnation of the bone at the fracture line with no evidence of trabeculation, and of bone absorption with a gap at the fracture site after a lapse of time which would normally be sufficient to permit healing. Fractures which show cystic changes in either fragment are not considered suitable for operation.

OPERATIVE PROCEDURE

The first bone-graft operation for fracture of the carpal navicular in this country was done by Adams and Leonard in 1928. Until 1934, however, the method had not come into general use. During this period it was recommended for non-union and pseudarthrosis. Autogenous bone grafts were taken from the tibia. Results following bone grafts were reported as uniformly good.

The procedure employed by the authors, which has been found to be generally successful, is as follows:

A dorsal longitudinal incision is made on the lateral side of the extensor pollicis longus tendon and is carried distally to the extensor crease of the wrist, which is followed transversely to the mid-point of the wrist (Fig. 1). It is necessary to recognize and avoid the superficial branch of the radial nerve. The description of the dissection which follows is made with the hand in the anatomical position of supination. Actually the hand is placed across the chest at operation. The extensor indicis proprius tendon is retracted medially with its tendon sheath. The other extensor tendons are retracted with this tendon, except the extensor pollicis longus tendon, which is retracted laterally. The dorsal carpal ligament is incised longitudinally, thus allowing for exposure of the capsule of the wrist di-

rectly over the navicular. The dorsal radiocarpal ligament and capsule are incised longitudinally, and sufficient room is thereby allowed to expose the bone with gentle retraction for almost its entire dorsal aspect. It is sometimes necessary, for better exposure, to move the tendon of the extensor carpi radialis brevis from its groove in the end of the radius and to retract it laterally. No harm has been seen to occur as a result of this retraction. Since the longitudinal portion of the primary incision of the skin is eight centimeters long, there is plenty of room to remove a bone graft from the distal quarter of the radius without including the metaphyseal end of the bone or disturbing the radiocarpal ligament. The fracture of the navicular is exposed; any intervening ligamentous or fibrous tissue is removed by sharp dissection, bone rasp, or curette; and the bone edges are fitted together. Three drill holes are then carried across from one fragment into the other fragment, leaving each bit in place. By leaving these three drill bits in place, the fracture is maintained in accurate position. Since one bit is removed at a time, and replaced by a bone peg, the driving of the pegs will not displace or separate the fragments, because the drills are placed at three different angles and pin the fragments tightly and firmly together. The proximal end of the incision is retracted laterally with the extensor pollicis longus and other extensor tendons, which is approximately at their musculotendinous junctions. The tendons of the extensor pollicis brevis, the abductor pollicis longus, and the extensor carpi radialis brevis are retracted medially. The distal fourth of the radius is now exposed, and the periosteum is elevated as far as the metaphysis. A graft of good cortical bone, one-half inch wide and one inch long, is removed. This large graft is split longitudinally to make three square

FIG. 1

Drawing of the operative procedure of triple-peg grafting of the carpal navicular. Shows the donor site and the three pegs in place. Inset demonstrates the type of skin incision which produces the least scar.

TABLE I

RESULTS IN NINETY CASES OF FRACTURE OF THE CARPAL NAVICULAR

	Number	Average Period of Immobilization (*Weeks*)	Union	Non-Union	Grafted	Disposition of Cases		
						Full Military Duty**	Restricted Military Duty**	Certificate of Disability Discharge
Fresh fractures	51*	7.4	45	2	2	46	0	0
Untreated fractures	39	0	0	39	10	16	18	5

* Five patients are still under treatment.
** Follow-up after six to eighteen months.

TABLE II

RESULTS IN CASES OPERATED UPON

	Number	Average Period of Immobilization (*Weeks*)	Union	Patients Discharged to:	
				Full Military Duty**	Restricted Military Duty**
Fresh fractures	2	9.6	2	2	0
Untreated fractures	10*	9.6	7	7	1

* Three patients are still under treatment.
** Follow-up after six to eighteen months.

peg grafts, one-eighth inch in diameter, which is the size of the drill bit. The drill bits are then removed one at a time and each is replaced by a peg graft, which is driven through to fix both fragments. After the drills have been removed and all grafts have been inserted, the wound is closed simply by suturing the capsule and then the dorsal transverse carpal ligament. All tendons fall nicely into place. The subcutaneous tissue and the skin are closed in layers. A cast is applied, similar to that used for a fresh fracture. This cast is removed at the end of six weeks and a roentgenogram is taken. The condition of the bones and the amount of union are checked, and, if union has not taken place, another cast is applied for three weeks. At the end of this time another check is made by roentgenogram, and either a cock-up splint or another cast is applied, depending upon the amount of healing. After union is complete, active motion, graduated exercises, and special wrist movements are combined with physical therapy to restore the normal range of motion and strength.

CLINICAL DATA

From March 1942 to August 1945, ninety cases of fracture of the carpal navicular have been treated. Of these, fifty-one were fresh fractures, treated either in the Orthopaedic Clinic or in the hospital (Table I). The average time required for union of these fresh fractures was 7.4 weeks; non-union was present in two cases. In these patients, grafting was subsequently done by the multiple-peg method, and bony union resulted. As might be expected, the fractures which took the longest time to heal were those through the waist or the proximal portion of the navicular. Those which were near the distal portion of the bone usually healed within six weeks. The patients returned to full duty with a painless, functioning wrist joint. A follow-up study was carried out on the soldiers who had had fresh fractures of the navicular, by writing to their respective commanding officers regarding postoperative care. The reports were made from six months to three years after the men had been discharged from further treatment. Reports were received concerning 62 per cent. of the patients with fresh fractures, and all were on full military duty, many of them overseas. Of the postoperative cases, follow-up studies showed all except one to be on full duty.

Thirty-nine old cases of non-union, which had had no previous treatment, were seen. The period of disability after the initial injury ranged from five months to eighteen years. It was always difficult to determine the amount of disability which resulted from non-union, and in every case the symptomatic findings were the guiding factors. Eighteen patients were placed on restricted duty, sixteen returned to full duty, and five were discharged from the Service with a Certificate of Disability Discharge because of complaints concerning the wrist. Ten of these patients were suitable for bone-graft operations. Of those who were placed on restricted duty, two had associated fractures of the lunate bone

and the first metacarpal, respectively. Another patient had an associated low-back pain, which necessitated placing him on limited service.

The twelve patients upon whom bone-graft operations were performed (Table II) had had recent fractures with definite evidence of non-union. The fracture lines were clearly defined at operation. The amount of mobility of the fragments seemed to depend upon the width of the fibrous tissue filling the gap. Either bone-end absorption or wider separation of the fragments in the first place resulted in more fibrous-tissue replacement. The authors believe that union in these operated cases would not have occurred after even two years of immobilization, because of the mobility, the width of the fibrous-tissue gap requiring replacement with bone, and the sclerosis of the fractured bone ends. The fibrous tissue did not have the appearance of preosseous tissue. After it had been excised and the sclerotic ends had been removed with a very small rasp or curette, even though actual bleeding of the bone surfaces was not evident, the bone appeared more nearly normal in texture. The average period of immobilization after operation was 9.6 weeks. In a few instances it was necessary to continue a cock-up splint for three or four weeks to ensure full bony union. Some illustrative case reports follow.

CASE 1. This soldier sustained a fracture of the navicular in May 1944. It was adequately immobilized for a period of eight weeks. Because absorption between the fragments of the fracture had taken place, it was decided that non-union would eventually result, and bone-grafting was therefore done. The cast was removed after eight weeks, and firm bony union was established by roentgenogram. The patient was discharged after rehabilitation, with a normal range of motion and complete function of the wrist (Figs. 2-A and 2-B).

CASE 2. This patient sustained a fracture of the carpal navicular in February 1944. No cast was applied. There was definite roentgenographic evidence of non-union. A grafting procedure with multiple pegs was done in July. The patient was discharged to full duty in November 1944, with complete bony union and full function of the wrist (Figs. 3-A and 3-B).

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 1. Non-union of carpal navicular. Marked separation of fragments can be seen.
Fig. 2-B: Same patient after triple-peg bone-graft operation.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 2. Non-union before triple-peg bone-graft operation.
Fig. 3-B: Position of grafts after union can be made out.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 3. Non-union before triple-peg bone-graft operation. Fragments are widely separated. Fig. 4-B: Complete bony union.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 4. Fracture of waist of carpal navicular, with angulation of fragments and non-union.
Fig. 5-B: After triple-peg bone-graft operation.

FIG. 6-A

FIG. 6-B

Fig. 6-A: Case 5. Shows non-union near proximal end of navicular.
Fig. 6-B: After triple-peg bone-graft operation.

FIG. 7

Case 6. Non-union after onlay bone graft and multiple drilling across the fracture site; peg graft was not used to bridge the fragments.

CASE 3. Fracture of the carpal navicular was incurred during military activity in October 1943. Non-union was established when the patient was seen in the Orthopaedic Clinic in June 1944. The soldier was operated upon in June. After operation he wore a cast for nine weeks and a splint for four weeks. He was discharged to full duty in October 1944, after bony union had been established; he had full function of the wrist and no pain (Figs. 4-A and 4-B).

CASE 4. The initial injury to the wrist occurred in July 1944. The patient received no medical treatment and a cast was not applied. Bone-grafting was done in September 1944. A plaster-of-Paris cast was necessary for twelve weeks, and the patient wore a splint for an additional three weeks. He was discharged to full duty in January 1945, with a completely healed wrist (Figs. 5-A and 5-B).

CASE 5. Bone-grafting of the carpal navicular was done on this patient five months after his initial injury. The cast was removed for the last time after ten weeks of immobilization; for part of this time he had been treated on an ambulatory basis. Due to lack of cooperation on the part of the patient in following the program of graduated exercises, there was some residual stiffness of the wrist, despite re-admission for the purpose of convalescence. This was the only patient in the series of cases which came to operation who was placed on restricted duty. It was felt definitely that this man would have had just as good a result as the others, if he had cooperated properly (Figs. 6-A and 6-B).

CASE 6. The patient was admitted to the hospital for bone-grafting in August 1942, after an injury to his left wrist. This was the second injury to this wrist; the patient gave a history of previous injury in 1938, while playing baseball. As this was the first operative case in the Service, it is presented to show the development of the method of grafting with three pegs. This patient had had multiple drill holes and one large onlay graft. He wore a cast for ten weeks, but no union occurred. Clinical fibrous union was present; but the authors felt that, if three pegs had been inserted into the three empty drill holes across the fracture, union might have occurred. Because of the experience with this case, the three pegs were used thereafter. Clinically, however, this patient had excellent function of the wrist with no complaints of pain. He was discharged from the hospital to full duty, and has been serving in the Armed Forces in that capacity ever since (Fig. 7).

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THE CONSERVATIVE TREATMENT OF CONGENITAL TALIPES EQUINOVARUS

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The medical literature is replete with hypothetical considerations of the etiology of this common congenital anomaly, but actually nothing new has been added since Hippocrates's description and discussion of congenital club-foot. The treatment since the days of Hippocrates had not materially changed until the *redressement forcé* was begun many years later. The modifications that followed were as numerous as the number of orthopaedic clinics the world over.

In his first paper in 1930, Kite himself disclaimed any originality for his method of treatment, stating that it was "as old as the science of medicine". Taylor, in 1892, reported his successful treatment of club-foot by what he called continuous leverage and retention in a cast. This was simply a method of treatment by a corrective cast, although without the refinement of wedges to help in the correction.

In this same year English orthopaedic surgeons began using metal splints in the treatment of club-foot. These, too, were modified many times in successive years, and in 1937 Denis Browne reported a new modification of this splint, the twelfth of its line; at that time he stated that the splint works on the mechanical principle that it is possible to correct the position of one foot by means of the other. In 1940 and 1941 a new modification of this splint was introduced in the United States.

Brockman, whose book on club-foot has become a classic, in a more recent paper about treatment of this condition, says: "After a long experience of the method of treatment upon which I was brought up—namely, repeated forcible manipulation of the deformed foot and fixation of the foot in the corrected position with plaster strapping—I have come to the conclusion that it is a poor method in every way when compared with the one advocated by Mr. Denis Browne."

Today, in considering any kind of treatment, it is necessary to pay attention to all the components of the deformity in order to make of the congenitally deformed foot one that is the exact opposite,—a hypercorrected foot.

The deformations are essentially three: adduction, inversion, and equinus. The adduction is located in the fore part of the foot and may be considered as an angulation between the fore part and the hind part of the foot, which takes place mainly in the mid-tarsal joint.

Peabody and Muro believe that it is necessary to differentiate the metatarsus varus component of talipes equinovarus from true metatarsus adductus,—a different entity without real changes in the position of the posterior part of the foot. The metatarsus adductus is, in their opinion, easily corrected; the metatarsus varus, generally with deformation of the metatarsal bones and cuneiforms, is very hard to correct.

The inversion takes place in almost the entire foot, but mainly in the subtalar joint; the talus is fitted into the mortise of the ankle joint, and the calcaneus in supination is rotated inward under the talus. The equinus deformity takes place, first, in the ankle joint, which is in plantar flexion and may be called "ankle equinus"; second, there is also the equinus of the fore part of the foot in relation to the posterior portion, called "forefoot equinus" or cavus, taking place in the mid-tarsal joint.

Any attempt to get a good correction of the club foot must accomplish the correction

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of all these deformities in sequence: adduction, inversion, equinus of the fore part of the foot, and equinus of the ankle joint.

First of all, the adduction of the fore part of the foot must be corrected in order that the navicular, which was medial to the head of the talus, be drawn in front of the head of that bone. This apparently simple deformation, perhaps the least important of any of them, sometimes is hard to correct, and gives the foot a characteristic appearance, with varying degrees of "toeing in".

Kite says that in the adduction deformity, if the navicular is still on the medial side of the head of the talus when the treatment is discontinued and the child is allowed to walk, the weight thrust will fall obliquely on the side of the navicular and will push the fore part of the foot back into the adducted position. If the fore part of the foot is carried outward too far, the navicular may be drawn around lateral to the head of the talus into a flat-foot position, which is undesirable. Care should be exercised to correct the adduction deformity completely, without overcorrecting it.

FIG. 1

"Rocker-bottom" deformity in a patient treated with the Denis Browne splint.

In the inversion or varus deformity, the calcaneus appears to be supinated under the talus, which is attached firmly into the tibiofibular mortise. This is the next deformity to be corrected. The third deformity to be corrected is the plantar flexion or equinus in the mid-tarsal joint. The last deformity is the equinus in the ankle joint, and no attempt should be made to correct it until the three other deformations have been corrected. This is of paramount importance since, with the foot in the equinus position, the subtalar joint is relaxed and it is easier to correct the adduction and varus deformities. When attempts are made to correct the equinus deformity without previous correction of the supination and adduction, the calcaneus will remain in the position of equinus and supination. The fore part of the foot is forced into dorsiflexion; and a converse deformity in the mid-tarsal joint develops, which is recognized clinically and roentgenographically as the "rocker-bottom" foot (Fig. 1).

The treatment of the club foot must be checked periodically by clinical observation and by roentgenograms. The anteroposterior films give a clear view of the deformation of the fore part of the foot against the deformations (adduction and inversion) of the posterior part of the foot; the lateral views show the equinus position in both the mid-tarsal and ankle joints.

The deformation of the fore part of the foot is checked by comparison of the alignment of the metatarsals with that of the tarsal bones. Kite believes that adduction of the fore part of the foot has not been corrected when the mid-line of the talus points toward the little toe instead of toward the great toe.

As the center of ossification of the navicular does not appear until the fourth year, this bone is not seen in roentgenograms taken before this age; until then the coincidence of the mid-line of the talus and the first metatarsal segment is used.

Normally, the calcaneus and the talus are fitted in such a way that the calcaneus articulates with the cuboid on the lateral border of the foot, and the talus articulates with the navicular on the medial border; both bones appear in the anteroposterior roentgenograms, forming an angulation of from 30 to 35 degrees. In the varus deformity the calcaneus is supinated,—that is, rolled under the talus, decreasing this angle. As the object

of treatment of the varus deformity is to pronate the calcaneus, the evidence of its accomplishment will be the separation of the anterior ends of both bones, as specified before.

When the equinus position is not corrected, the lateral roentgenograms will show the talus extending over the calcaneus by half its length; at the end of successful treatment, the anterior ends of both bones are more or less in the same transverse plane.

In the past, the treatment of club-foot in this Orthopaedic Department followed one of three methods: (1) initial treatment by frequent changes of casts; (2) attempts to attain full correction at one sitting by means of a wrenching and lengthening of the tendo calcaneus under anaesthesia; and (3) initial treatment by manipulation under gas anaesthesia.

For the last few years some changes have been made, and at present the treatment falls into one of the following categories, depending upon the age of the patient when first seen:

1. Splints.
2. A wedged cast, or the Kite method.
3. Manipulation under anaesthesia, with some restrictions.

With a clear understanding of what a club foot is and what procedures are necessary in order to correct the deformations, an analysis will be made of the three principal conservative methods of treatment which are being used in this Clinic, and their limitations will be discussed.

1. *The Denis Browne Splint in the Treatment of Congenital Club-Foot*

Brockman's opinion of the splint has already been stated. In 1941, Stuart Thomson of Toronto introduced the splint into the United States. He stated that the results of treatment with older methods were discouraging, while in sixty cases of equinovarus deformity treated by him with the Denis Browne splint, there was only one recurrence (blamed entirely upon the mother).

Van Domselaar, of Buenos Aires, presented in 1943 a report based upon his experience at the Campbell Clinic in Memphis, Tennessee. Of twenty-eight cases treated by means of the Denis Browne splint, there were twenty-six cases with excellent correction and two failures (one because of intolerance to adhesive strapping, and the other due to multiple deformities and lack of cooperation of the parents). Correction was obtained in from four to eight weeks, except in one case (treated previously with manipulation and casts) which took nine weeks. His report is very optimistic, but the follow-up of the cases is insufficient.

A paper by Jergesen in the same year, on unilateral club-foot treated by the Denis Browne splint, and another by Bell and Grice in 1944, bring the bibliography on the subject up to date. Many minor modifications of the original splint have been made, and most of the details have already been described.

In the Orthopaedic Department of the University of Iowa Hospitals, a type of plate is employed which is similar to that used by Bell and Grice; it is made in three different sizes, according to the size and age of the child. Lately, since more attention is being paid to adduction of the fore part of the foot, the shape of the plates has been changed so as to make them curve outward, with a concave lateral border and a convex medial border. A special device is placed under the plates, to allow rotation of the plate on the bar.

The horizontal bar is flat, and does not differ from that described by other authors. The plates are covered with felt instead of rubber sponge; this is stuck on the surface of the plate, facing the foot. The technique of strapping follows more or less the plan generally used. It is, of course, necessary to keep certain principles in mind to assure success by this method:

1. There must be perfect apposition and attachment of the foot to the plate.
2. In order to prevent oedema, no windows should be permitted between the strips.
3. There must be no wrinkles, to avoid excoriation of the skin.
4. The skin must be clean, and must be prepared by washing with tincture of benzoin.

Since more attention has been paid to the correction of the adduction of the fore part of the foot, the authors have adopted Bell and Grice's technique in applying the first two strips. In the bilateral cases, both feet are bound to the plates according to this technique. In the unilateral cases, the normal foot may be strapped in a similar manner, but it is not necessary to follow a special technique; it is enough to have the normal foot firmly flat on the plate.

It is better to begin by holding the foot or feet on the plates for a short while in the position of deformity,—that is, not to attempt immediate correction of the adduction, inversion, and equinus. With this idea in mind, the bar is bent to the shape of an inverted V and applied to the plates without changing the position of the foot. This has some advantages: The flexibility of the foot is increased; there is no swelling; dermatitis is minimized; and the foot always remains soft, which greatly facilitates the treatment.

At first the strapping is changed every five to eight days,—preferably every five days. The authors prefer to keep the patient in the Hospital during the first period of treatment,—that is, from four to eight weeks; then he is discharged, provided there is assurance of proper home care and of prompt return, at stated intervals, for continuation of the treatment.

After two or three sessions, the bar is straightened out, and, as the feet follow the position of the bar, the adduction and inversion become diminished until the neutral position in the anteroposterior plane is obtained. From then on, the foot is gradually rotated and abducted until it reaches 90 degrees of outward rotation. As long as the bar is kept straight, adduction is corrected and inversion is reduced to the neutral position. To change the varus into a valgus deformity, the bar may be bent to assume a true V shape earlier,—that is, starting when the foot points straight forward. The former way—namely, the anteroposterior position with 90 degrees of external rotation on the bar (the so-called "Charlie Chaplin" position)—is the usual procedure.

In subsequent sessions, when adduction and inversion have been corrected, one starts the stretching of the calf muscles. This is done by accentuating the V bend of the bar while the foot is still held in 90 degrees of outward rotation. When the deformity is unilateral, the bar on the normal side is bent horizontally so that the foot is held in a neutral anteroposterior position all the time.

The treatment with the Denis Browne splint is active treatment: The more the baby kicks, the more the correction is improved; when flexion movements at the knees are carried out, the feet go into valgus and the calf muscles are stretched. The active kicking results in marked development of the calf muscles. The progress of correction is checked by roentgenograms, according to the standard criteria mentioned previously.

After the correction of all the deformities has been accomplished, the problem is to maintain this correction. Thomson allots five or six weeks for correction, about five months for use of the splints, and another six months in boots; after the child begins to walk, shoes are used during the day and splints at night,—for years, if necessary.

Bell and Grice do not like the use of shoes attached to the plates, or the use of plaster casts in order to maintain the correction. They advocate the use of the plates with the feet strapped on them for at least a year.

Van Domselaar states that, after correction has been obtained within six or eight weeks, the plates are attached to baby shoes with a small corset stay for the legs. After the child is seven months of age normal shoes, attached to the bar, are used.

In this Clinic the policy is to start the treatment as early as possible; correction was obtained in the favorable cases in about eight weeks. After correction it is advisable to use the plates and bar, as Bell and Grice do, for a long period of time. When the baby is old enough to wear shoes, they are attached to the plates in reverse (the left shoe on the right side and the right shoe on the left side), and the splints are worn twenty-four hours every day. After two to four months the mother is instructed to allow the child to wear the

FIG. 2-A

FIG. 2-B

Show patient before and after treatment with the Denis Browne splint.

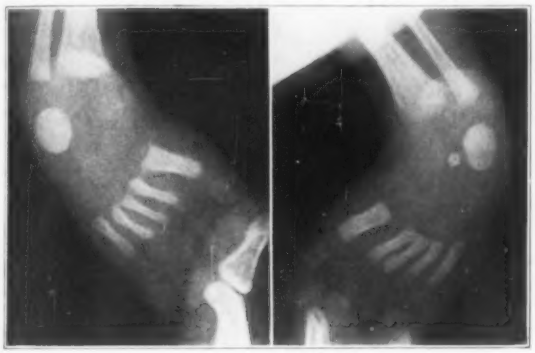

FIG. 2-C

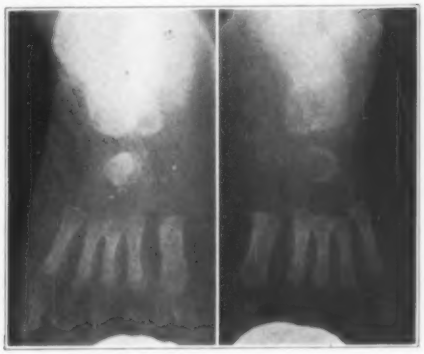

FIG. 2-D

Roentgenograms taken before and after treatment.

splints twenty hours each day, and to be without them the other four hours. When the baby reaches the walking age, a similar program is followed: The splints are worn at night and during napping hours for a long period of time, and shoes with outer patches on the soles are worn for standing and walking. In some instances club-foot plates are placed in the shoes, in addition.

Van Domselaar cites twenty-eight cases; the ages of the patients ranged from three weeks to four and one-half years. Correction was obtained within four to eight weeks. The results were excellent in twenty-six cases; failures occurred in two cases.

Of forty-six cases, Bell and Grice obtained excellent results in eleven, good results in twenty-nine, and fair results in six. They considered an excellent result to mean an essentially normal foot (external rotation with a full range of dorsiflexion and eversion). A good result meant a foot without structural changes, but with some limitation of motion as compared with the normal. A fair result was one in which a mild deformity of one of the elements persisted, but did not cause any appreciable disturbance in gait.

This report covers cases treated by the Denis Browne method in the Orthopaedic Department of the University of Iowa Hospitals from 1942 to 1945, inclusive. The cases are divided into two groups: The first group includes patients treated only with Denis Browne splints; the second group includes cases in which treatment was started with Denis Browne splints and completed by other types of conservative treatment.

From February 1942 to November 1945, of 161 cases of congenital club-foot, forty-one were treated from the beginning with Denis Browne splints. In twenty-eight of these cases the deformity was bilateral and in thirteen it was unilateral, giving a total of fifty-nine cases of club-foot.

The age at onset of treatment varied from two weeks to one year; most of the patients (nineteen, or 46.3 per cent.) were between two and six weeks old, eight (19.5 per cent.) were two months old, and 12 (29.3 per cent.) were between three and five months of age,—a total of thirty-nine patients under six months of age. Two patients were over six months of age. Most of the cases, therefore, were treated very early. The period of observation varied between four months and three years.

The results were as follows:

1. Excellent correction of all these components—adduction, inversion, and equinus—was obtained in 21.5 cases, or 53 per cent. (Figs. 2-A, 2-B, 2-C, and 2-D).

2. Correction of the deformity, with but a slight degree of metatarsus adductus remaining, was attained in ten cases, or 24 per cent.

3. More than one of the components of the deformity were still present in 9.5 cases, or 23 per cent. (The figures of 21.5 and 9.5 each include a case in which one foot was corrected and the other was not.)

Of the second group, in which treatment was started with the Denis Browne splint and completed with another form of conservative treatment, full correction was obtained in four cases after treatment of the adduction with Kite casts. In four cases of the same group, wrenching was advised and was refused. One patient has had the Kite cast, without success to date. In one case, correction of the remaining metatarsus adductus with the Denis Browne plate is still being attempted. It is possible that, in some of these cases, wrenching or the Kite casts will be needed to obtain complete correction.

Of the 9.5 cases in which more than one component of the deformity was still present, correction was obtained in five after treatment had been completed with wrenching or the Kite casts.

It is evident that these results with the Denis Browne splint alone are not so optimistic as those published elsewhere. The cases in which success was attained with the Denis Browne splint alone, together with those in which the Denis Browne splint was complemented by another type of conservative treatment, total almost the same as, or more than, those of most of the other authors; only Kite's own results with wedge casts are better. If to the 53 per cent. of excellent results are added the cases with good results after use of the Kite casts or wrenchings in the second and third groups, the total is almost 80 per cent. of good results with conservative treatment.

The better functional results with the Denis Browne splint, alone or complemented with other conservative treatment, are possibly due to the fact that the feet are almost always kept flexible with the use of the splints.

2. *The Kite Cast or Wedged-Cast Method*

We are all familiar with the excellent description given by Kite of the steps in applying the casts and taking the wedges. In this method also, one is concerned with correction of the adduction of the fore part of the foot, then with the varus of the heel and the correction of the cavus, and finally with the correction of the equinus in the ankle joint. It is important that wedgings be made once or twice a week, and that a completely new cast be applied after every three or four wedgings. When all the components have been corrected, the foot should be maintained in the corrected position in a retentive cast for several months. These casts, too, should be changed every few weeks; and at these times the knee and ankle joints should be put through a complete arc of motion. Small wedges taken frequently, without undue strain being put on the joints and their soft structures, may take somewhat longer to attain full correction, but assure a more satisfactory foot, both from the cosmetic and from the more important functional standpoint. Meticulous care in applying the casts and taking the wedges is essential.

Forty-three cases were treated by this method. The ages ranged from seven days to thirteen months at the onset of treatment. Two patients had had retentive casts applied

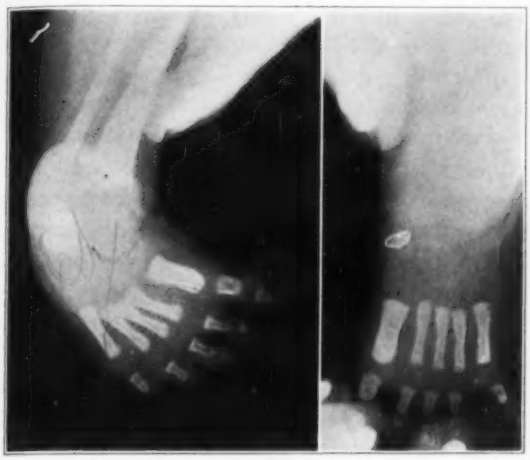

FIG. 3-A

FIG. 3-B

Roentgenograms taken before and after treatment by the Kite method.

by local physicians prior to their first admission to this Hospital, but no attempt had been made by the local physicians to obtain any correction. The duration of treatment ranged from two to thirteen months. In eleven cases there were recurrences, which were re-treated with Kite casts. One patient had the Brockman treatment in conjunction with the Kite treatment. Six had lengthenings of the tendo calcaneus to correct residual equinus. In thirty-two cases, or a total of 74.4 per cent., the results were good (Figs. 3-A and 3-B). This does not include the five cases which were first treated by the Denis Browne splint and then by the Kite method. Of these, four had good results and one had a poor result. Eleven cases, or 25 per cent., had poor results. They were later treated by wrenchings and plantar strippings, and will probably eventually come to bone operations. Of these, three were cases of spina bifida.

A comparison of these statistics with those of Kite shows that the authors obtained good results in fewer cases than did Kite.

3. *Manipulative Treatment under Anaesthesia*

Fifty-seven patients (eighty-one feet) were treated exclusively by corrective casts and wrenchings, except for two cases in which Kite casts were used for short periods between

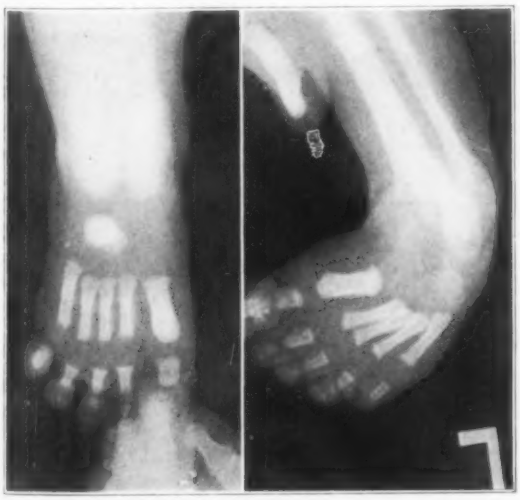

FIG. 4-A

FIG. 4-B

Before and after treatment by wrenchings.

wrenchings, without improvement. They represent all the cases of club-foot that were treated by manipulation between 1940 and 1942. This period of study was chosen for two reasons: first, to give a sufficient follow-up period for determining late end results; and second, because, after 1942, many of the cases were treated by combinations of wrenchings, Denis Browne splints, and Kite casts. The word "wrenching" is used here to denote forceful manipulation under anaesthesia, without the use of the Thomas wrench and wedged bar.

During this period thirty-six cases, with a total of fifty-four club feet, were treated in the Clinic by the Resident Staff. (Since there were a number of bilateral cases in which one foot required additional operative work to complete the correction, the statistics are given according to the number of feet and not according to the number of cases.) Of this number, correction was complete in ten feet, or approximately 19 per cent., and six feet were corrected except for a slight adduction of the fore part of the foot, giving a total of good results of approximately 30 per cent. (Figs. 4-A and 4-B). Of the sixteen good results, eleven had to have lengthenings of the tendo calcaneus to complete the correction. Five were corrected without such lengthenings. These cases all have roentgenographic evidence of the correction.

In the private cases where the wrenchings were done by Dr. Steindler, the statistics are much better. The basis for correction rests mainly on clinical impression, however, because during the period of study, roentgenograms were taken infrequently on private cases. In most cases, the follow-up has been sufficiently long to show that the correction has been maintained, and in no case where clinical correction had been reported was there found later to be roentgenographic evidence of residual deformity. This is not true of the cases treated in the Clinic, as often clinical impressions have been found to be at great variance with the roentgenographic picture.

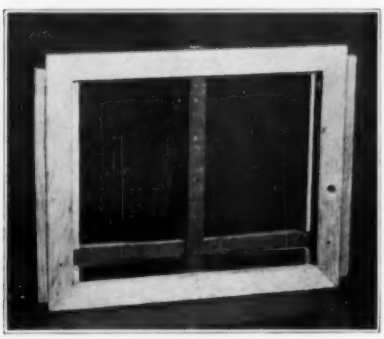

FIG. 5-A

Special cassette holder for the standardization of roentgenograms.

FIG. 5-C

FIG. 5-B

There were twenty-one private cases, with a total of twenty-seven abnormalities of the feet. Complete correction of all components by clinical or roentgenographic evidence was obtained in seventeen feet, or approximately 63 per cent. In two feet the deformities were corrected, except for slight adduction of the fore part of the foot, making a total of nineteen acceptably corrected feet, or 70 per cent. Deformities in twelve of the feet were completely corrected without lengthening of the tendo calcaneus. In both partially corrected feet, lengthening of the tendo calcaneus was required. Of the private cases, correction was obtained in eleven feet with one or two wrenchings, three were corrected with three wrenchings, and the remainder required from five to ten. The average length of time between wrenchings was one month, but ran up to one year, owing to recurrences of the deformity.

In the Clinic cases in which correction was achieved, two or three wrenchings were required. One case was corrected with one wrenching, and one case required seven. The average length of time which the patients spent in casts before complete correction was obtained ranged from three months to two years in the private cases, and from four months to four years in the cases treated in the Clinic; two and one-half years was the average for the Clinic cases and one and one-half years for the cases privately treated.

The age at onset of treatment ranged from six weeks to four or five years in both the cases seen in the Clinic and privately. In the Clinic, twenty-five patients were under six months of age and eleven were over six months of age; nine private cases were under six months of age and twelve were over six months. Of the patients treated successfully by this method in the Clinic, nine were under six months of age and seven were older. Of the series seen privately, ten were under six months of age and seven were over.

It might be well to re-emphasize that an attempt to correct the equinus should not be made until the adduction and varus have been corrected. Lengthenings of the tendo calcaneus were carried out in some of the cases treated by manipulation, prior to obtaining correction of the other components. This was a definite factor in causing failure of correction in these cases. In evaluating the cases in this series, fairly rigid criteria have been maintained for complete correction of adduction of the fore part of the foot.

A special cassette holder fashioned out of wood, with two crossbars, is now used (Fig. 5-A). The posterior part of the heel and the entire medial side of the foot are held firmly against the horizontal and vertical bars, respectively (Fig. 5-B). All roentgenograms are thus standardized (Fig. 5-C).

Most of the well-corrected congenital club feet treated by wrenchings are pliable. Incompletely corrected feet are usually rigid. This is mentioned, since it has been reported and is generally believed that all feet treated by wrenchings are rigid. A private patient, in whom wrenching for severe club-foot was carried out twenty years ago by Dr. Steindler, was seen recently. Roentgenograms showed perfect correction, and no evidence of bone injury or degeneration. The feet were pliable and painless.

With the use of the wedged-cast method, Kite reports successful treatment in 90 per cent. of his cases. He maintains that forcible manipulation under anaesthesia irreversibly damages the articular cartilage, which results in partial or complete ankylosis. The authors agree with this statement only in so far as the cases incompletely corrected by manipulation are concerned. In the cases treated by manipulation under anaesthesia in which complete correction was obtained, the feet were found to be pliable. In reviewing the roentgenograms of 100 consecutive cases treated by manipulations, which include the cases in this series, in only three cases was there some evidence of bone injury. In one case there was aseptic necrosis of the first cuneiform; in one there was a separation of the lower tibial epiphysis; and in one some destruction of the talus was present.

It is perfectly evident that we are dealing with a condition which is amenable not only to treatment, but to cure, provided proper management on the part of both the physician and the parents is brought to bear.

COMMON CAUSES OF FAILURE

Kidner stated that there are three principal causes of failure:

1. Delay in inauguration of treatment.
2. Imperfect nerve supply to the muscles, as in spina bifida.
3. Failure to obtain and to maintain complete overcorrection of the deformity.

With regard to the first cause of failure, it is obvious that, with the use of the Denis Browne splint or the Kite casts, the earlier treatment is started, the better the prognosis. However, with the manipulative treatment under anaesthesia, this factor does not appear to be so important. It is often the fault of the parents that a baby with club-foot is not brought for treatment, but more frequently the fault lies with the family physician.

The second reason is self-evident. The third reason needs some elaboration. Kite, in 1935, stated that "an incompletely corrected club-foot or a relapsed club-foot is more disabling than an untreated club-foot. The untreated foot is more stable and is a much more serviceable foot than a partially corrected foot."

No matter what the treatment, the maintenance of correction is of utmost importance. We have all seen too many cases in which complete correction, both clinically and by roentgenogram, is obtained, only to be lost in subsequent months because of failure to maintain the correction in some suitable manner.

It is likewise of importance that the period of time between the reapplication of the Denis Browne splints should not be longer than from five to seven days,—preferably five. With the Kite method of treatment, wedges should be taken every three or four days and casts should be changed completely after every third wedging. One of the reasons why Dr. Steindler obtained better results in his private cases was that he manipulated the feet every three weeks or every month until correction was obtained.

A fourth cause of failure may be allergic manifestations to adhesive strapping and plaster-of-Paris. In several cases, another form of treatment had to be used because of allergic reactions to these materials.

Maintenance of correction should be active until all the tarsal bones are completely ossified. The parents should be instructed in their part of the after-treatment, and should be deeply impressed with their responsibility of gentle manipulation of the corrected feet

FIG. 6-A

FIG. 6-B

Fig. 6-A: Roentgenograms of patient with metatarsus varus, before treatment.
Fig. 6-B: Roentgenograms taken after treatment by wrenchings.

Fig. 7-B: Very good result was obtained after treatment by wrenchings and rententive casts.

Fig. 7-C: Show recurrence of the deformity one year later.

Fig. 7-D: Aug. 28, 1942. A very good result was obtained with a bilateral Brockman's operation, lengthening of the tendo calcaneus, and Kite casts.

Fig. 7-E: Jan. 10, 1946. The patient did not return the next year for follow-up; now, at the age of seven years, wedge osteotomies will be necessary.

FIG. 7-A

Roentgenograms of a patient at nine weeks of age.

FIG. 7-B

FIG. 7-C

FIG. 7-D

FIG. 7-E

several times daily. They should also be impressed with the fact that they are to bring the child back immediately upon the recurrence of the slightest deformity.

The authors advocate the following regimen in the maintenance of correction: When

complete correction has been obtained, and only then, are the Denis Browne plates and bar attached to the soles of the shoes, with the right shoe on the left foot and the left shoe on the right foot. This arrangement is worn continuously until the child reaches walking age. The child is then fitted with a club-foot plate and full-length outer patches on the shoes.

The plates must be changed frequently to fit the foot. The club-foot plate is a flat piece of metal, the width and length of the foot, with three flanges or lips; one is on the lateral side of the foot, opposite the tarsometatarsal joint, and two are placed medially. The anterior lip opposes the head of the first metatarsal, and the posterior lip opposes the heel. This fits into the shoe and holds the foot in the position of correction. For a child who is active and walking, this is a valuable form of after-treatment for the waking hours, if properly fitted.

When the child first begins to walk, he is allowed to be up two hours a day for the first few months. The rest of his waking and sleeping time is spent in the shoes and the Denis Browne splint. The hours of freedom from the splint are gradually increased, depending upon the judgment of the physician; however, the splint is always used at night for at least two or three years after correction.

In regard to the metatarsus varus alone, without the other deformities, several of these cases have been treated with Denis Browne splints without success; on the other hand, a number of cases of metatarsus varus were treated with Kite casts with good results. The vast majority of the cases of metatarsus varus were treated by manipulation (Figs. 6-A and 6-B). Twenty-six feet in the private cases and ten feet in the series seen in the Clinic were thus treated. Of the private cases, twenty-three had excellent results, two improved, and failure occurred in one case. Of the cases seen in the Clinic, complete correction was obtained in eight and partial correction in two.

Certain disadvantages are associated with each of the three methods:

With the Denis Browne splint, constant attention is required. The adhesive strapping must be changed every five to seven days, which necessitates frequent visits or long periods of hospitalization, entailing considerable expense.

Use of the Kite casts requires frequent wedges and changes of cast, which also entail frequent treatments or a prolonged stay in the hospital. In addition, the personal equation of the doctor treating the patient is of utmost concern, because of the necessity for meticulous care in the taking of wedges and the application of casts.

Manipulation under anaesthesia has the following disadvantages:

1. An anaesthetic is necessary, with all the risks involved.
2. The period of immobilization in plaster is longer.
3. The personal equation is of greater concern here than with the wedged-cast method.
4. There is danger of permanent bone or joint changes. This is, of course, inversely proportional to the experience of the orthopaedic surgeon instituting the treatment.
5. Frequent upper respiratory and contagious diseases prevent the giving of anaesthetics, which cause undue delay and interruption of treatment.

The maintenance of correction is of the utmost importance, and cannot be emphasized too strongly. In this regard, one case is illustrated in which correction was not maintained because of failure to retain the foot in the corrected position for a prolonged period (Figs. 7-A, 7-B, 7-C, 7-D, and 7-E).

CONCLUSIONS

1. Treatment of club-foot should be instituted as early as possible.
2. The Denis Browne splint, alone or complemented in some cases by another form of conservative therapy, gives the best results, especially in patients under one year of age.
3. In cases in which the Denis Browne splint failed to obtain complete correction, or

in those patients who are between one and four years of age at the beginning of treatment, wedged casts should be used.

4. In some cases of metatarsus varus, correction can be accomplished with wedged casts.

5. Under certain conditions in private practice, manipulative methods may not be the method of choice, but rather of necessity. In expert hands, good results can be obtained by the manipulative method.

6. The manipulative method can be used in patients in the older age groups.

7. Metatarsus varus can either be completely corrected or markedly improved by manipulative methods.

8. Correction must be maintained for a considerable period of time, preferably as described.

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A SPLINT FOR TREATMENT OF RECURRENT CLUB-FOOT *

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About a year ago a new splint was designed at our clinic for the final treatment of recurrent club-foot. It has been named the "spring splint", and has proved to be of outstanding value and satisfaction. It is applicable only to the child of active-walking age.

The recurrent club foot usually shows varying degrees of the following deformities:

(1) Equinus—the foot cannot be dorsiflexed to a right angle;

(2) Varus—this varies considerably in different feet and may even remain as a subtalar varus permanently, in spite of treatment;

(3) Adduction of the fore part of the foot, which is not of much consequence, and tends to correct itself when contraction of plantar fascia has been obviated.

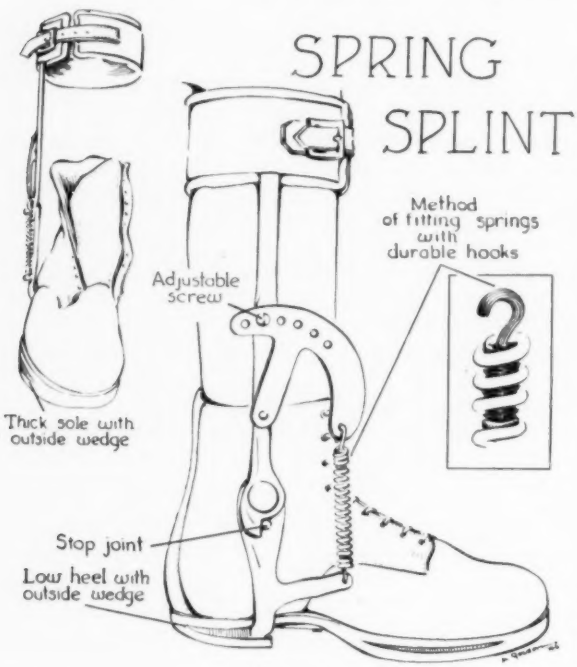

FIG. 1

It has been our custom to have the patient admitted to the Hospital and given a general anaesthetic. If the degree of equinus is not very great, only a plantar fasciotomy and manipulation may be done, followed by application of a plaster cast. It may be necessary to do one or more manipulations at intervals of three or four weeks. When the fore part of the foot can be readily dorsiflexed to a right angle or better, the patient is ready for the spring splint.

When a club foot can be dorsiflexed to a right angle or more, the recurrent tendency is greatly lessened; moreover, the adduction and varus deformities (if still present) become lessened spontaneously. On the other hand, if the degree of equinus is great, it may be necessary to do a lengthening of the tendo calcaneus and a posterior capsulotomy. This procedure may be followed by one or more manipulations and possibly by a plantar fasciotomy as well.

Prior to the use of this splint, the parents were then instructed in daily manipulation of the feet, and the patient was provided with boots. Repeated recurrence was frequent, until finally an arthrodesis was decided upon.

Since the advent of the spring splint, the results in recurrent club-foot have improved tremendously. The splint is applied when correction to a right angle or better has been obtained. At the start, it is kept on night and day. No further manipulations by the parents, or exercises, are necessary. However, the patient is encouraged to take up roller-skating, ice-skating, and skiing, because these sports all require repeated and active degrees of dorsiflexion.

Since the spring splint has been used, our operative measures and the number of manipulations have been greatly modified. In other words, many patients, upon whom a tendon lengthening would formerly have seemed necessary, now require only a plantar fasciotomy. The splint does the rest of the work.

* The Denis Browne method of treating club-foot[1] still remains a highly efficient one with an excusable number of recurrences.

The design of the splint is simply a lateral single bar below the knee brace, with a stop joint. It is fitted on our standard club-foot boot, which is a good boot with a low heel and a thick sole and an outside wedge of three-sixteenths of an inch on heel and sole. The two segments of the splint are then united by an adjustable hinge-like apparatus with an intervening spring.

The springs are manufactured in three sizes to suit the varying sizes of both child and splint. A great deal of difficulty was encountered at first, because the springs were breaking at the point of contact with the splint, due to inevitable friction. This has been overcome by removing the hook end, which was just a continuation of the spring coil, and replacing it with a much stronger hook. The new hook is embedded in a metal plug which is threaded inside the spring.

FIG. 2-A

FIG. 2-B

Demonstration of boots for club-foot.

The specifications of the springs, which are made of music wire, are as follows:

	Small	*Medium*	*Large*
Diameter of wire	0.036 inch	0.048 inch	0.064 inch
Outside diameter of spring	0.25 inch	0.344 inch	0.375 inch
Number of coils	24	24	26
Tension at one-inch pull	9 lbs.	14 lbs.	22 lbs.

Six of the medium-sized springs are used to every one of the small or large springs.

Too much tension must be avoided, particularly at first, because of danger of a pressure sore either on the heel posteriorly or over the anterior aspect of the ankle. Additional methods of preventing this complication are to pad the tongue of the boot and to be sure that it is firmly laced, so that the heel is well down in place and unable to shift its position. The adjustable screw (Fig. 1) makes doubly sure that the tension is correct.

This splint has also been used satisfactorily on children beginning to walk after correction has been obtained, but in whom inevitable recurrence, due to lack of parental care, is feared. However, it is not used in the routine treatment of club feet which have responded satisfactorily and are being well supervised.

The reverse model of this splint has proved helpful in the treatment of a few cases of calcaneovalgus club feet.

NOTE: The writer wishes to express his sincere thanks to the Orthopaedic Shop at the Hospital for Sick Children for its continuous and courteous help and expert workmanship.

1. THOMSON, S. A.: Treatment of Congenital Talipes Equinovarus with a Modification of the Denis Browne Method and Splint. J. Bone and Joint Surg., **24**: 291–298, Apr. 1942.

THE TREATMENT OF PARALYTIC CALCANEUS

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PHYSIOPATHOLOGICAL CONSIDERATIONS

The calcaneus foot (talipes calcaneus) is not an infrequent sequel of anterior poliomyelitis. It follows paralysis of the triceps surae. The following pathological phenomena appear as a consequence of paralysis of the sural triceps:

1. *Loss of Flexion of the Foot*

With loss of function of the calf group the gait is steady, but greatly handicapped. It is impossible not only to plantar-flex the foot, but also to propel the body forward. Because of this, it is necessary in walking that the center of gravity of the body be kept posterior to the ankle in order to avoid automatic extension (dorsiflexion) of this joint. Consequently, it is necessary to shorten the forward swing of the other limb.

2. *Progressive Elongation of the Triceps Surae*

As a result of stretching of the paralytic calf group, there is an increase in the range of passive motion of the ankle in extension. This modifies the normal physiological stimulus, which influences the bony development of the talus. In consequence, the shape of the talus becomes altered, and the head and distal portion of the neck assume a more elevated position in relation to the rest of the bone.

3. *Loss of Balance between the Plantar Muscles and the Triceps Surae*

In this condition the calcaneus may be influenced by the plantar muscles only, thus altering the mechanical stimuli which normally affect the growth of this bone; the part exposed to the plantar-traction stimulus keeps on growing, and the posterior part becomes atrophied. The calcaneus becomes more and more deformed, until the heel attains its characteristic form,—that of the butt of a pistol. Likewise the lever arm of the calcaneus is shortened. As the weight-bearing surface of the calcaneus is reduced, balance becomes difficult.

4. *Increase of the Talocalcaneal Angle*

In the author's opinion, all anatomical and mechanical changes are represented by the increase of the talocalcaneal angle (*AOC*, Fig. 1). The importance of this angle was discovered by the author during a study of Professor Putti's cases of paralytic calcaneus at the *Istituto Ortopedico Rizzoli*, Bologna. Normally, the axis of the talus, that of the first metatarsal, and that of the calcaneus meet at a point which we call the "axial center" (Fig. 1). The talocalcaneal angle has a normal value of about 50 to 55 degrees. The increase of this angle represents calcaneus deformity, and consequently the amount of this increase indicates the anatomical and static changes.

5. *Trophic Changes in Joint Capsules and Ligaments*

The ligaments and capsules, especially of the talotibial and subtalar joints, are affected by poliomyelitis. Consequently, there is not only an increase in the passive motion of these joints (flexion-extension in the ankle, pronation-supination in the subtalus), but, what is far more important, abnormal motion occurs.

In the ankle, lateral movement is usually in the direction of pronation. As a result, growth of the external part of the talar body is less than normal. A vicious cycle of deformity and abnormal mobility is established.

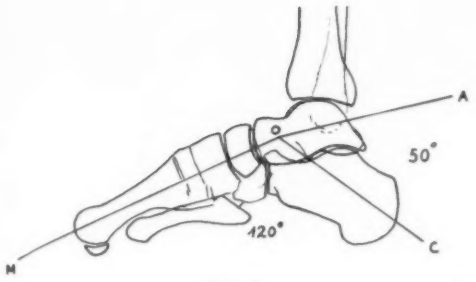

FIG. 1

Fig. 1: Axes and angles in the normal foot. *O*: Axial center. *A*: Axis of astragalus (talus). *M*: Axis of first metatarsal. *C*: Axis of calcaneus.

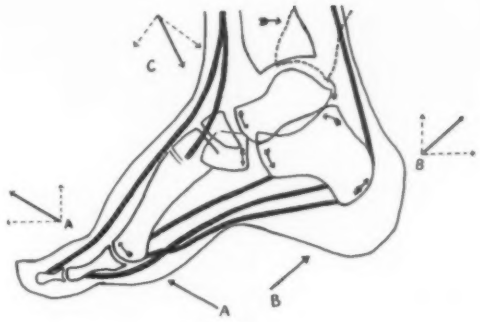

FIG. 2

The axes are determined as follows: A roentgenogram is made, with the lateral surface of the foot resting upon the cassette. Lines are then drawn, (1) bisecting the first metatarsal, (2) from the tip of the posterior tubercle of the calcaneus through the deepest point on the calcaneal surface of the sinus tarsi, and (3) from the posterior border of the upper articular surface of the talus through the center of the head of that bone.

Fig. 2: *A*, *B*, and *C* show the three forces which must operate to correct a calcaneocavus foot, after it has been placed in plantar flexion.

In the subtalar joint, in addition to an increase of lateral movement, it is possible to find pathological motion of flexion-extension. This movement is slight; but, by means of hand pressure (Figs. 3-A, 3-B, and 3-C), a modification of the talocalcaneal angle can be demonstrated. Consequently, it is possible to speak of a calcaneal rotation, produced by the tension of the plantar fascia and muscles, which is added to the anatomical changes in this bone.

6. *Other Physiopathological Relations in the Foot*

In addition to the changes mentioned, talipes cavus appears frequently in the calcaneus foot. The action of the plantar muscles, as well as that of the extensors of the great toe and the peroneus longus, can intervene in its pathogenesis. The geometrical representation of the cavus deformity is the increase of the angle formed by the axis of the calcaneus with that of the first metatarsus, and the division of the axial center (Figs. 4-A, 4-B, 5-A, and 5-B). Likewise, when the tibiales are paralyzed, calcaneus flat-foot may follow. In this case the talocalcaneal and the metatarsocalcaneal angles are increased.

The paralytic syndrome in the foot has more or less functional importance, according

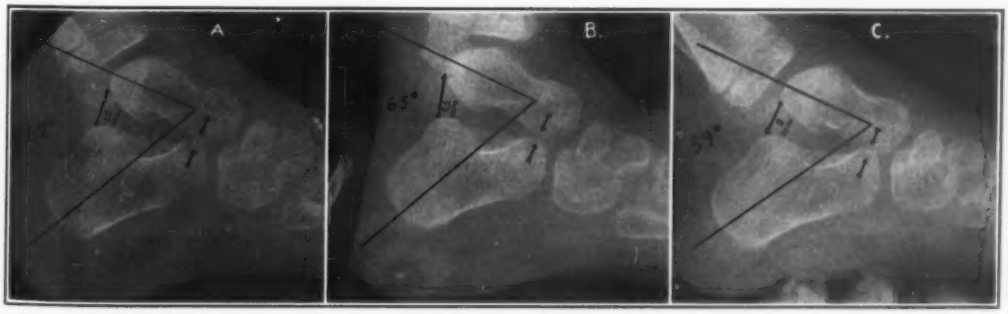

FIG. 3-A FIG. 3-B FIG. 3-C

Roentgenograms of a calcaneus foot (slight deformity).

Fig. 3-A: Normal position of the foot.

Fig. 3-B: Increased deformity, due to pressure over the back of the calcaneus and to stretching of the plantar muscles.

Fig. 3-C: Deformity corrected by means of pressure over the lower aspect of the calcaneus. The talocalcaneal angle can be modified, thus proving a pathological mobility at the level of the subtalar joint. In order to show clearly the space between the talus and the calcaneus, the talar axis was traced through the most prominent part of the posterior surface of the talus, which is seen in the roentgenogram. For this reason the size of the angle is greater than normal, because the talar axis was not traced in the correct position (See Fig. 1).

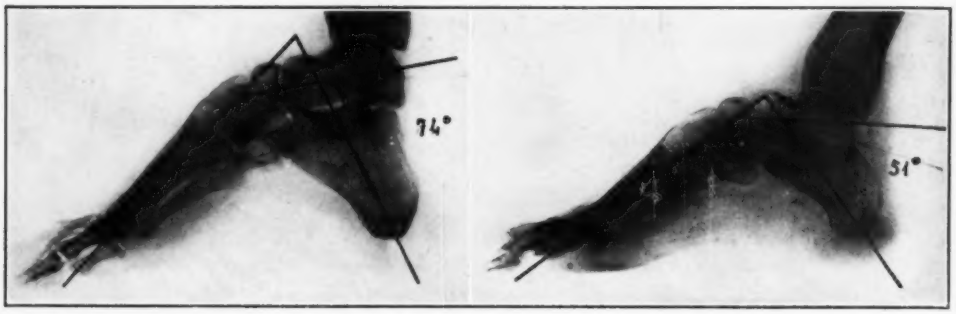

FIG. 4-A FIG. 4-B

Calcaneocavus foot before and after cuneiform subtalar arthrodesis. Note the displacement of the axial center, which remains in spite of the fact that the back of the foot is maintained in physiological position (talocalcaneal angle of 51 degrees). There exists, then, a cavus of the fore part of the foot, which must be corrected.

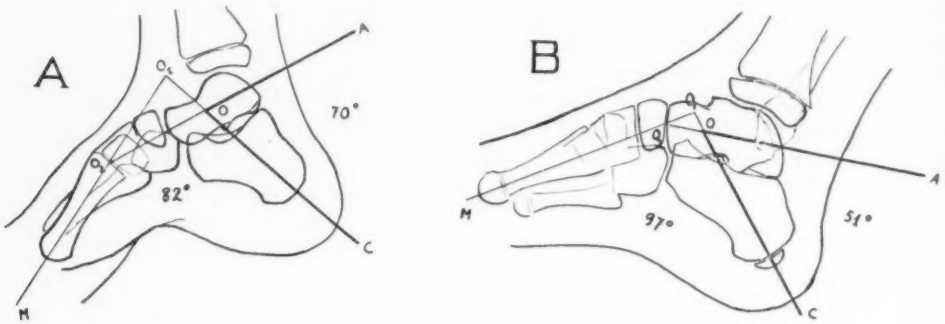

FIG. 5-A FIG. 5-B

Tracings of roentgenograms of a calcaneocavus foot, before and after subtalar arthrodesis and anterior arthrorisis, according to Putti's second method (one year after surgical intervention). The calcaneus deformity has been corrected. The morphology of the calcaneus and talus approximates normal. A slight cavus in the fore part of the foot still persists.

to the functional condition of the limb. If the quadriceps is paralyzed, the gait is greatly handicapped; and, if the glutei are also paralyzed, walking becomes impossible. Likewise, if the knee is contracted in flexion, weight-bearing becomes impossible, because of the displacement of the center of gravity.

All these considerations must be taken into account before treatment is undertaken.

TREATMENT

During Period of Recovery

After the acute stage, postural treatment is necessary. The foot is maintained in flexion to counteract the pull of the plantar muscles. If deformity is just beginning and the triceps retains any force, this procedure may be sufficient to correct the deformity (Fig. 2).

After the Deformity Has Become Established

The function of the triceps can, theoretically, be provided by transplantations, but it is necessary to consider, as Fick does, that the triceps has a force of 16.37 kilograms. The sum of the force of the other muscles of the leg is 6.58 kilograms. This means that transplantations can help in improving function, but they are not sufficient to avoid the pathological consequences of triceps paralysis.

In theory, stretching of the triceps can be treated by tenodesis or by shortening of the tendo calcaneus; but elongation appears again, if not prevented by other means.

Hyperextension of the foot can be prevented by arthrodesis or by arthrorisis (arthrocreisis) of the ankle. After the first operation, the tibiotalar joint is rigid and the gait is

FIG. 6-A
Normal side.

FIG. 6-B
Paralytic side.

FIG. 6-C

FIG. 6-D

Same patient after the operation (subtalar arthodesis, anterior arthrorisis, and transplantation of both the peroneal muscles to the calcaneus).

Fig. 6-C: Plantar flexion. Fig. 6-D: Dorsiflexion that shows the action of the arthrorisis.

FIG. 6-E

FIG. 6-F

FIG. 6-G

Fig. 6-E: Active dorsiflexion. Fig. 6-F: Active plantar flexion.
Fig. 6-G: The weight-bearing on the fore part of the foot is satisfactory.

unsatisfactory. Moreover, the calcaneus can continue to rotate, and it is necessary also to perform a subtalar arthrodesis. This may be indicated when the ankle possesses great instability and when the fore part of the foot is not deviated, in order that the mediotarsal joints may afford sufficient compensation. The operation of choice is the anterior bone-block. By this operation, passive hyperextension of the foot is prevented and the normal growth of the talus is permitted (Figs. 5-A, 5-B, 6-A, and 6-B).

PUTTI'S TECHNIQUE[2,3]

An anterior incision is made from the lower tibial epiphysis to the level of the mediotarsal joint, with the foot in extreme plantar flexion. Care must be taken to avoid the musculocutaneous nerve. The incision is then carried inward, between the extensor digitorum communis and the extensor hallucis longus. The anterior tibial artery and nerve are retracted medially with the long extensor of the great toe, thus exposing the capsule of the ankle joint. Formerly Putti opened the joint; later this exposure was abandoned in an effort to avoid traumatic joint changes. Immediately distal to the capsular attachment to the talus, a curved osteotome is gradually introduced into the bone in the horizontal plane. As the instrument penetrates the cancellous bone, an upward prying force is gently imparted to it. It is generally sufficient to osteotomize the bone to a depth of 1.5 centimeters.

The lamina thus created is pried up cautiously as far as possible. With reasonable care, fracture can be avoided. Of the forty-odd cases in the author's experience, fracture has been avoided in all. This is attributed to two factors: first, the gentle upward prying with each successive penetration; and, second, the thickness of the osseous lamina, which should not exceed three millimeters.

When a block, sufficient to limit dorsiflexion of the foot at the predetermined angle, has been obtained in this way, a cancellous bone graft is impacted into the osteotomy slot, while the blade of the osteotome is still in place. The blade is then withdrawn. The graft used has been prepared previously, at the time of the subtalar arthrodesis.

Tendon transplantations are performed at this point, if indicated.

In the author's modification of the operation, when the talus is in the valgus position, correction is obtained through greater lateral elevation of the lamina. The plaster cast is worn for three months, maintaining the foot in equinus, or in equinovarus when the modification has been performed. Exercises and progressive weight-bearing are then permitted, the patients walking with crutches.

In time, the block attained at operation decreases; but, under the stimulus of weight-bearing, the bone becomes hypertrophied, and sufficient check can be expected if weight-bearing is controlled. Excessive weight-bearing before organization of the elevated bone tends to lower the block and results in too much dorsiflexion. On the other hand, a slight amount of weight-bearing—such as for five or ten minutes daily—actually stimulates the bone and hastens the remodeling of bone structure until this becomes adequate. This may require from two to four months of careful supervision, during which time weight-bearing is progressively increased.

The typical deformity of the heel is easily corrected, and may be prevented by subtalar arthrodesis, which also reestablishes the normal value of the talocalcaneal angle. Usually the arthrodesis should be wedge-shaped; the quantity of the wedge to be extirpated is indicated roentgenographically by the opening value of the talocalcaneal angle. Moreover, subtalar arthrodesis prohibits pathological motion in this joint, and makes the support stable and the gait more secure. The lateral motion in the talocalcaneal joint is treated by the modified arthrorisis of Putti. In this modification, the lateral portion of the upper articular surface of the talus is raised, thus correcting the valgus (Figs. 6-C to 6-G).

Mention should be made of the associated paralysis of the quadriceps femoris. If passive hyperextension of the hip and the knee had been present prior to operation, this

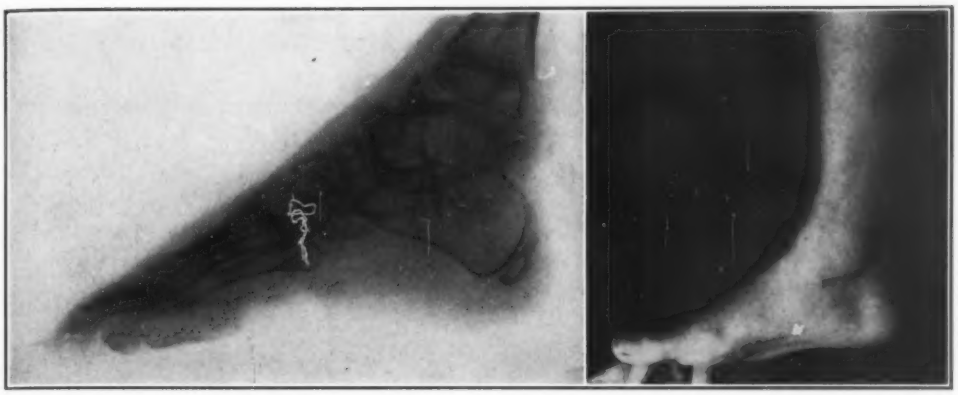

FIG. 7-A FIG. 7-B

Roentgenogram and photograph of a calcaneovalgus foot three years after subtalar and mediotarsal arthrodesis and anterior arthrorisis.

condition was automatically corrected mechanically by the arthrorisis, provided it blocked the ankle at 100 degrees. This was demonstrated by Putti.

END RESULTS

The series presented herewith has been taken from a group of fifty cases of paralytic calcaneus foot observed in the *Hospital Central de la Cruz Roja de Madrid* and in the *Instituto Nacional de Reeducación de Inválidos*, Madrid. Twenty-five patients were operated upon; twenty-one were suitable for arthrorisis, which in thirteen was anterior, and in eight anterolateral. In order to correct such conditions as valgus, varus, or cavus deformities, or claw-foot, calcaneocuboid and talonavicular arthrodeses have in some cases been necessary, as well as tendon transplantations. Seventeen of the twenty-one patients have been considered satisfactory for end-result study from the standpoint of time and proper follow-up.

In all of the seventeen patients, subtalar arthrodeses were performed; in seven, transplantations of the peronei were possible. Peroneal transplantations will probably be performed later in a number of these cases, when the children are sufficiently mature to cooperate in reeducation of the transplanted muscles. Their ages varied from four to fifteen years, with the majority between five and thirteen years of age.

Examination by the author of the series of cases operated upon by Putti disclosed uniformly good results when the extra-articular technique had been employed properly, and the after-care could be carried out. These patients had been operated upon many years before. In them no osteo-arthritic changes were found, and the full mechanical effect of the bone-block proved to be lasting.

The end results have been considered from the standpoints of form and function. Results have been considered to be "good", morphologically, when the foot was of approximately normal appearance clinically, and by roentgenogram the talocalcaneal angle was shown to be between 50 and 55 degrees. The result is recorded as "poor" if there was valgus, varus, or a flat foot.

Functional results have been estimated with consideration of the muscle power present before operation. A patient, lacking muscles suitable for transplantation, was considered to have a good end result when dorsiflexion at the ankle was limited at 90 degrees. The result was also considered to be "good" if a patient who had "fair" transplanted muscles, subtalar arthrodesis, and anterior arthrorisis could walk "over the toes" (Fig. 6-G).

The result is considered "poor" if the block corrects dorsiflexion of the ankle at an angle, formed by the long axis of the leg and the foot, which is less than 90 degrees. If

paralysis of the quadriceps exists and the bone block does not arrest dorsiflexion at the ankle at from 90 to 100 degrees, the arthrorisis will not result in hyperextension of the knee in walking, and the result is considered poor.

The author's series is too recent to justify final conclusions in these respects. Six patients were examined four years or more after arthrorisis. Of these, four, or 67 per cent., are considered to have functionally good results; in two, or 33 per cent., the results are poor. Eleven patients were examined from one to three years after arthrorisis; provisionally, the results in nine, or 82 per cent., were considered good, and in two, or 18 per cent., poor. The poor results in both series of cases are due to insufficient bone-block, and a second operation has therefore been performed on these patients. The second operation was not technically difficult.

No arthritic changes or abnormal growth of the lower tibial epiphysis has been observed as yet in this series. Morphologically, all patients are considered to have attained good results.

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TREATMENT OF CONGENITAL FLAT-FOOT *

BY JAMES E. M. THOMSON, M.D., LINCOLN, NEBRASKA

The medical profession has been criticized for lack of recognition and adequate correction of many disabilities which showed up in Army inductees who appeared before Selective Service examiners. Among the common foot disabilities was symptomatic flat-foot, in various degrees of severity. The questions which are frequently raised with respect to the foot complaints of the adolescent and young adult are as follows:

1. Why should healthy-looking, well-developed young men be afflicted with poor feet? They may or may not have a long history of foot trouble. Sometimes their symptoms are attributed to military training.

2. Would it be reasonable to suggest that they had from babyhood exercised and developed their musculoskeletal system normally, with perhaps the exception of their feet?

3. Might it not be possible to develop criteria by which one might early (before walking is begun) recognize those feet which might be potentially weak or show pronation? To investigate such a problem, the pediatrician must look for and recognize physical anomalies and evidences of weakness in the baby's foot and realize that, just because a child does not have club-foot, he does not necessarily have normal feet.

Several frequently observed characteristics of the infant's foot, which seem to bear a definite relation to future foot weakness or to act as potential forerunners of flat feet, will be discussed.

FIG. 1

FIG. 2

Fig. 1: Congenital weakness of the foot is readily recognized by hyperflexibility, particularly the ease of ability to place the dorsum of the foot in the calcaneovalgus position against the leg.

Fig. 2: Pronounced pronation and eversion are shown as the child crawls.

Some infants have abnormal mobility of the foot in all directions, and a particular fondness for an everted calcaneovalgus position. These babies have the tendency to throw their feet, while kicking, from a varus to an extreme calcaneovalgus position. Usually the dorsum of the foot can be brought manually, without force, against the anterolateral part of the leg (Fig. 1). These babies are often belly sleepers, and in this position they habitually evert their feet. When they learn to sit, they assume a position of abduction, with the

* Read by J. Warren White, M.D., at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1946.

knees flexed and the feet everted. The eversion of the feet is exaggerated during crawling (Fig. 2). When the infant begins to walk, the legs rotate outward, and pronation and eversion of the feet are thereby exaggerated (Fig. 5-A).

On the basis of five years of observation, the author believes that the characteristics described above constitute a distinct objective entity, which signifies congenital weakness of foot structure. These findings are far more common than is realized. The deformity accompanying the manifestations may to a certain extent be overcome by growth, development, and activity of the child, or by late recognition and adequate therapy. We believe, however, that many of these children have "foot complaints" at some time before or after adolescence.

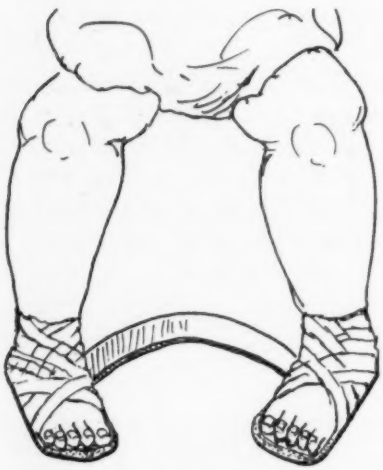

FIG. 3

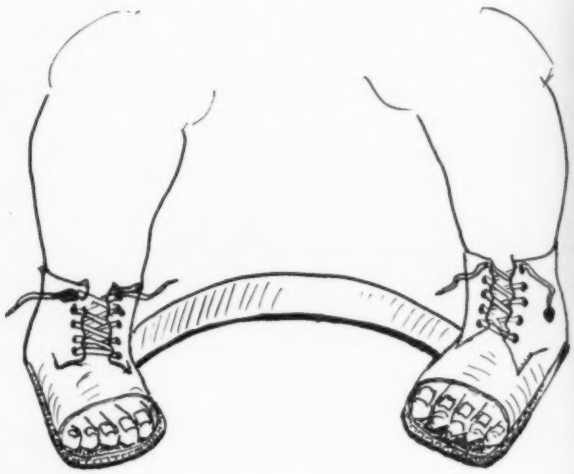

FIG. 4

Fig. 3: Sketch of the reverse Denis Browne splint, with the bend of the bar toward the crotch.

Fig. 4: Shoes with toes cut out are used for older children. When the child begins to walk, the splint is used at night.

TREATMENT

For some years the author has used the Denis Browne splint in certain cases of club-foot, with satisfactory results. In one instance of a unilateral club foot, the opposite foot was abnormally mobile and had a tendency to calcaneovalgus posture. In this case an attempt was made to turn the varus foot out and the valgus foot in by means of the same splint. An S-shaped cross iron was prepared so that the club foot was on the down side and turned out and the valgus foot was on the up side and turned in. As the child exercised the legs and feet in order to correct the club foot, the valgus foot became more varus and stable. It is difficult to tell now, after three years, which is the varus and which the valgus foot.

This experience led to the use of a Denis Browne splint in reverse for the treatment of congenital talipes calcaneovalgus. Instead of having the cross bar bend away from the crotch as it does in the correction of club-foot, it is bent toward the crotch; and instead of the foot plates being turned out, they are turned in. Therefore, this treatment is referred to as the reverse Denis Browne splint (Fig. 3).

TECHNIQUE

1. As in the treatment of club-foot, the earlier a foot weakness is recognized, the shorter is the period of treatment and the more gratifying the result. Therefore, the optimum time to begin treatment is when the infant is from one to three months of age.

2. The foot plates are strapped on after the foot has been painted with compound tincture of benzoin; strapping is carried out exactly the same as for club-foot. Because of the usual hyperflexibility of the foot, it can be inverted in extreme correction on the bar, which is bent toward the crotch. A masking tape (made of crepe paper), three-quarters of an inch wide, when reinforced by one-inch cotton bandage, is tolerated longer by the skin than is adhesive tape. Re-strappings are made every one to three or four weeks. The feet are watched carefully between strappings.

3. As soon as the foot has developed in size sufficiently to take a hard-soled shoe (size one or two), the shoes are riveted to the plates. The toes of the shoes are always cut out to allow penetration of air and freedom of motion (Fig. 4). A carefully trimmed, well-fitted, soft sponge-rubber pad is pasted in the shoe to follow the normal longitudinal contour of the arch. Its purpose is much the same as that of overcorrection of clubbing by the wedging of casts. The aim is to promote the normal contour of the foot by a mild lift in this region during muscular activity. The child is seen every month or two during the next six or seven months; and, as the foot increases in size, the shoes are changed on the plates and the cross bar is lengthened. Splints are removed daily for bathing and massage and for an hour or so of freedom.

FIG. 5-A

FIG. 5-B

Fig. 5-A: A child, ten months old, has pronounced foot weakness.

Fig. 5-B: Same child, at age of four years, has strong feet. Splints were worn for four months during the day, and then used only as night splints. Child wears mildly corrective shoe.

4. At the age of ten or twelve months the child is fitted with walking shoes. Again, longitudinal soft pads are fitted and are glued into the shoes. Sometimes a lift inside the heel is advisable. The child is encouraged to take his first steps. When the child has his nap and at bedtime, the reverse Denis Browne splint is put on and its use is continued until the child's foot shows a normal response to all exercises and activities. The length of time, of course, varies for every patient. When the treatment is started early, the splints are often dispensed with between the ages of one year and fourteen months. When treatment is started late, night splints have been required even up to two

FIG. 6

Denis Browne splint treatment was recommended when this child was six months old, but it was refused. At four years, the patient complains of his feet and shows marked weakness.

years of age. Heel lifts, Thomas heels, and sometimes soft pads inside the shoe must be continued indefinitely. Exercises after three years of age are most valuable when there is proper parental cooperation.

COMMENT

Faulty posture, instability, and abnormal mobility are all aggravated by habit. When these characteristics are combined with congenital weakness of the infant foot, the condition must be corrected by the following means: Proper muscle activity in the right, or overcorrected, posture must be developed and new habits of the intrinsic foot muscles as well as of the extrinsic leg muscles must be created. Furthermore, by the apparatus described, which encourages proper muscle activity in a corrected position, the weakness can be overcome and the defects can be corrected.

Over fifty patients from one to four years of age have been observed, and the results have been uniformly gratifying (Figs. 5-A and 5-B). In a smaller group of control cases, the arduous ordeal of the splint treatment was refused. Most of these children, although still quite young, have pronated valgus feet and several are already symptomatic (Fig. 6). A few, however, have developed fairly normal feet. The question, of course, remains as to what will happen to these patients later in life.

Since the congenital club foot is usually a foot with limited possibilities, many of the congenital flat feet which have been treated, although they look normal, may require continuous supportive measures and exercise in order to maintain normal function.

DISCUSSION

Dr. Lenox D. Baker, Durham, North Carolina: Dr. Thomson described the use of the Denis Browne splint in the treatment of calcaneovalgus deformities of the foot in one of his Orthopaedic Correspondence-Club letters. During the past year we have used the splint, as suggested by Dr. Thomson, and have been most pleased with the early results. The splint has its limitations; it is of little or no use in the foot with a long talus, and it is of little permanent benefit in a foot with an accessory navicular. As Dr. Thomson has pointed out, its greatest use is in the uncomplicated calcaneovalgus deformity. The splint brings about an early correction of the valgus deformity; and in many of our cases we have seen a rapid return of active inversion, and have seen the posterior tibial and the abductor of the great toe brought back into active participation in the motions of the foot.

Dr. J. Warren White, Greenville, South Carolina (closing the discussion in the absence of Dr. Thomson): I find no points of disagreement with Dr. Thomson's data, and only wish to mention a simple expedient, which in my hands has been most useful as a supplementary procedure.

Some parents, as Dr. Thomson has inferred, refuse to permit the use of a splint of this nature before the child begins to walk, particularly because the abnormality—one cannot call it a deformity—seems so trivial.

The reverse Denis Browne splint is much simpler than the plaster casts which we have all been using on the severe cases. Since Dr. Thomson described the procedure in his Correspondence-Club Letter, I have been using it when necessary, concluding the treatment, however, with a yet simpler procedure, which has been used solely in the mild cases.

In those instances, therefore, where an even more conservative method may be desired, I have been sticking together the soles of these infants' hypermobile flaccid feet with a commercial adherent or compound tincture of benzoin, and holding them with a two-inch elastic bandage. In many instances we tend to neglect treatment in children with everted feet, and it is particularly in these cases that the sole-to-sole position for maintaining equinovarus is indicated.

We hold the soles together until the child maintains the inverted position most of the time, which is usually in three or four months. There has been no objection to the method on the part of the parents. They are afraid of a splint, but will tolerate putting the feet together.

We all are indebted to Dr. Thomson for calling to our attention the need of doing something about these functionally disordered feet, and for suggesting a practical method for the correction of the severe cases.

INTERNAL FIXATION OF TROCHANTERIC FRACTURES OF THE FEMUR

Report of 103 Consecutive Cases

BY ROBERT M. O'BRIEN, M.D., JAMES C. SHY, M.D., AND NORBERT J. BUBLIS, M.D.,
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During the past few years, considerable interest has been shown in the operative treatment of trochanteric fractures of the femur. In many clinics, this treatment has become almost as standardized as the operative fixation of fractures of the neck of the femur.

The purpose of this paper is to present a satisfactory operative technique, and to point out the advantages of operative treatment,—lowered mortality, shortened convalescence, and improved anatomical and functional end results.

The authors' conclusions are drawn from experience gained in the operative treatment of 103 consecutive cases on the Orthopaedic Service of the St. Louis City Hospital. Excluded from this report are three patients who refused surgery and four who, for reasons other than the fractures, were moribund on admission.

The average age of the patients in this series was 70.6 years. The youngest patient was fifty-two years old; the oldest was eighty-nine.

TABLE I
Types of Anaesthetics Used

	Number of Cases	Number of Deaths	Mortality (*Per cent.*)
Spinal anaesthesia	29	4	13.8
Ether (drop)	10	2	20.0
Pentothal sodium and nitrous oxide	34	3	8.8
Local anaesthesia	30	13	43.4
Totals	103	22	21.4

ANAESTHESIA

Table I illustrates the types of anaesthetics and their relation to mortality. Noteworthy is the mortality rate of 43.4 per cent. for local anaesthesia, as compared with 8.8 per cent. for pentothal sodium and nitrous oxide. These figures do not represent selection of cases. In the early part of the series, local anaesthesia was used almost entirely in the belief that it was to be preferred in this age group. The results did not justify this opinion. Insufficient relaxation, incomplete loss of sensation, and operative shock undoubtedly contributed to the high mortality associated with local anaesthesia.

Because the results with local anaesthesia were not satisfactory, the combination of pentothal sodium and nitrous oxide was used. Reduction of the fracture was carried out under pentothal anaesthesia. The operation was then begun, and 50 per cent. nitrous oxide was given, with just enough pentothal to keep the patient in light anaesthesia. Rarely has it been necessary to give more than a total of one gram for the entire procedure. Although some of the poorest operative risks were included in the pentothal group, the mortality rate dropped to 8.8 per cent.

OPERATIVE TECHNIQUE

The use of an orthopaedic fracture table is desirable, particularly when the fracture is badly comminuted or the surgeon is inexperienced in this procedure. In all of the cases

in this series the operations were performed on this type of traction table, with the following technique:

After the patient has been anaesthetized, both legs are fastened in abduction to the traction apparatus of the table. Sufficient mechanical traction is then applied to the affected leg in full internal rotation to produce a valgus reduction.

Portable roentgenograms are now made in the anteroposterior and lateral planes. A curved cassette for the lateral view and a wooden perineal post facilitate roentgenography.

When the adequacy of the reduction has been proved by roentgenogram, the base of the greater trochanter is palpated; and an incision is made, from the trochanter downward for about six inches, on the posterolateral aspect of the thigh. Curving the superior and inferior ends of this incision slightly forward will expedite medial retraction of the soft tissues. The fascia lata is incised, and the shaft of the femur is exposed, either by cutting directly through the vastus lateralis or by reflecting its origin from in front of the greater trochanter and the linea aspera. The periosteum is elevated, and a half-inch hole is carefully drilled through the proximal femoral cortex, care being taken not to shatter the bone and thus complicate the situation by creating a subtrochanteric fracture. This hole is made at, or slightly above, the level of the lesser trochanter.

A Kirschner wire, three thirty-seconds of an inch in size, is now directed through this opening, upward into the neck and head of the femur. Roentgenograms check the position of the wire. If necessary, adjustments are made. By measuring the length of wire protruding from the femoral shaft, the operator can select a blade-plate of the proper length. In most cases, the length of the cervical element of this plate will be three inches or less. With the wire as a guide, the blade-plate is driven into the femoral head.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Mrs. D. R., aged seventy-five. Patient had a comminuted intertrochanteric fracture.

Fig. 1-B: Six weeks after internal fixation with Neufeld nail-plate.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Mrs. M. B., aged seventy. Shows the intertrochanteric fracture, immediately after operation, held in good position by a Neufeld nail-plate.

Fig. 2-B: Roentgenogram taken not quite four weeks later. Bending of the plate has occurred at the upper screw hole. It is possible that this accident might have been avoided if a screw had been placed in this hole.

FIG. 3-A

FIG. 3-B

Mr. L. G. This patient began full weight-bearing on his own responsibility, before solid union had occurred, and the nail broke three months after the operation.

FIG. 4-A

FIG. 4-B

FIG. 4-C

Fig. 4-A: Mrs. A. C., aged seventy-seven. Patient had a comminuted intertrochanteric fracture.

Fig. 4-B: Shows same fracture, five days after operation, with internal fixation by means of the Moore blade-plate.

Fig. 4-C: Three months after operation. Impaction of the inferior portion of the fracture has occurred, causing medial migration of the blade point, with penetration into the hip joint. This complication could have been prevented by using a shorter blade.

A third set of roentgenograms verify the position of the blade If satisfactory, the plate portion is fixed to the femoral shaft with screws, the diameter of which should be at least one sixty-fourth of an inch greater than that of the drill points used. The screws must firmly engage both cortices of the bone. A depth gauge is invaluable in selecting screws of the proper length.

The wound is closed in layers. A heavy pressure dressing with an elastic-bandage spica of the hip is helpful in controlling muscle and bone bleeding after operation.

The operation, including time for roentgenograms, usually requires about one hour and a half. Efforts to shorten the procedure by omitting roentgenographic control will often result in prolonging the operation, and may end in disaster.

Since this series was completed in March 1945, the operation has been performed on seventy-four additional patients on this Service, bringing the total to 177. Beginning in July 1945, a shorter operative method[1] has been used in many instances. The procedure is carried out on an ordinary operating table, without the guide wire, and roentgenograms are taken only to check the final position of the nail-plate. This technique will cut the operating time in half, but should be used only by surgeons who are familiar with the operative treatment of trochanteric fractures.

TYPES OF INTERNAL FIXATION

The type of internal fixation to be used depends upon the choice of the operator and the nature of the fracture. In this series, the Neufeld femoral nail-plate was used in ninety cases, the Moore blade-plate in eight, and the Smith-Petersen nail with the Thornton attachment in five patients. In the authors' hands, the one-piece nail-plate was simpler and easier to use than the combination of the Smith-Petersen nail and the Thornton plate.

The V-shape of the Neufeld nail possesses two advantages: It will not cut out of the femoral head, and it will follow a guide wire more closely than the Moore type. Theoretically, the V would seem to weaken the nail-plate at its angle. In the ninety cases of fixation with the Neufeld nail in this series, the nail-plate did bend at its angle in one case. In two other patients, bending occurred just below the angle, at the upper screw hole (Figs. 2-A and 2-B).

The eight Moore blade-plates used had flat, straight blades. This feature permits adjustment of the angle with special bending irons, and possibly overcomes some of the angle weakness. The flat blade has a tendency to cut out of the head, however; this happened in one case. The newer type of blade-plate, which is convex on its superior surface, will probably overcome this objection, although neither type will follow a guide wire as well as the Neufeld nail.

POSTOPERATIVE CARE

On the day after operation the outer elastic bandage is removed, and the patient who is a poor risk may sit up in a chair. The average patient is allowed up in a chair after about five days. Partial weight-bearing on crutches is begun at the end of six weeks; full weight-bearing is not permitted until there is demonstrable roentgenographic evidence of union. This is usually in about four months.

Quadriceps-setting exercises and flexion exercises of the hip and knee are begun on the first day after operation. Since these exercises are an important feature of the postoperative care, they must be constantly enforced and supervised.

The early freedom of movement possible after operative treatment is a tremendous advantage. The incidence of pneumonia and of decubitus ulcers is reduced markedly, and the psychological stimulus to the patient is inestimable.

COMPLICATIONS

The usual postoperative complications of any surgical procedure tend to occur. As a group, however, these patients have done exceedingly well, despite their age.

Fig. 4-C: Three months after operation. Impaction of the inferior portion of the fracture has occurred, causing medial migration of the blade point, with penetration into the hip joint. This complication could have been prevented by using a shorter blade.

FIG. 5-A

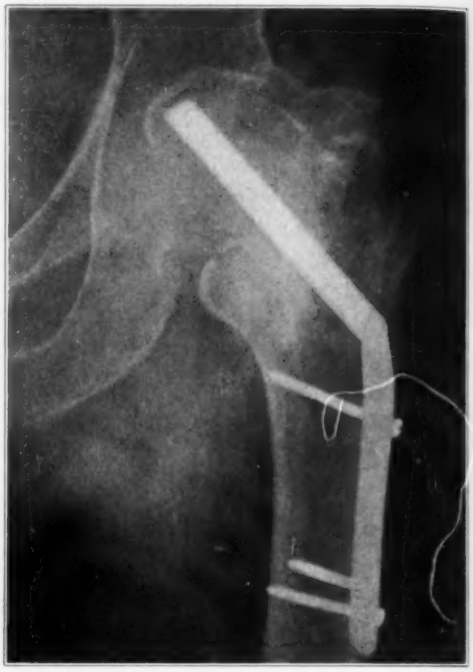

FIG. 5-B

Fig. 5-A: Mr. J. V., aged sixty-eight. Shows intertrochanteric fracture, held in satisfactory position by a Neufeld nail-plate. However, the nail has been placed too near the articular surface of the femoral head.

Fig. 5-B: Roentgenogram, taken six months later, shows the proximal end of the nail protruding into the hip joint. A shorter nail would have averted this frequent, but preventable, complication.

Bending of the nail-plate has been mentioned. In one case, a year after operation, the patient had a serious fall, which caused the nail-plate to break just below the angle, and produced a displaced subtrochanteric fracture. On his own responsibility, another patient began full weight-bearing before union had occurred, and the nail-plate broke three months from the date of operation (Figs. 3-A and 3-B).

An important preventable complication is medial protrusion of the cervical portion of the nail-plate into the hip joint. This happened ten times in the earlier part of this series. Some degree of medial migration of the nail-plate was present in many more cases (Figs. 4-B, 5-A, and 5-B).

Screw fixation of the plate to the femoral shaft prevents extrusion of the nail part from the femoral head. If bone absorption with shortening occurs, the nail tends to increase its penetration of the femoral head. To forestall this difficulty, the authors have adopted the standard that, after the nail has been placed, there should be at least one-half inch between the medial end of the nail and the articular surface of the head of the femur. A nail-plate whose cervical element is longer than three inches will rarely be required.

MORTALITY

In the group of cases studied there were twenty-two deaths,—a mortality rate of 21.4 per cent. In a similar series of operated cases described by Taylor, Neufeld, and Janzen, the mortality rate was almost identical,—21.6 per cent. In sharp contrast to these figures is the mortality rate of 39.2 per cent. reported by Leydig and Brookes for 302 trochanteric fractures treated conservatively at the St. Louis City Hospital several years ago. Harmon describes a mortality of 39 per cent. in 164 patients treated by non-operative methods.

RESULTS

In this series of 103 cases, twenty-two patients died. A follow-up of from one year to two and one-half years was possible on fifty of the eighty-one survivors.

The authors classed as "excellent" the results in those patients who had normal motion of the affected hip and knee, normal gait, no pain, good anatomical restoration by roentgenogram, and ability to return to their usual duties or occupations. In this group there were twenty cases (40 per cent.).

Classified as "good" were the results in those patients who had subjective complaints or slight limp, but walked without a cane or crutch and performed the same occupation as before injury. This classification included eleven persons (22 per cent.).

In eight cases (16 per cent.) the results were considered "fair" because, although weight-bearing on the affected extremity was normal or nearly normal, the patient walked with the aid of a cane or crutch.

Those patients who were unable or unwilling to bear any weight on the fractured extremity were classed as having "poor" results. In this category were eleven, or 22 per cent.

Dealing as we are with a group of individuals whose average age was 70.6 years, and including persons up to eighty-nine years, it is evident that the usual methods of classifying end results of fractures will be necessarily misleading, since they do not consider factors, other than the actual fracture, which might cause poor results. In this series, senile dementia, general debility of the aged, and coexistent disease compromised the results in many cases.

Of the eight patients whose results were considered only "fair" because each used a cane or crutch, most had excellent anatomical results on the basis of physical and roentgenographic examinations. The authors believe that, for at least some of these people, the cane or crutch was unnecessary; and its use was often the expression of habit or desire for security on the part of an elderly person.

Of the eleven cases in which the results were designated as "poor", the authors believe that only one represented a failure of the method; in this patient, marked bending of the nail occurred. In four others the results were due to faulty technique—usually the use of too long a nail—which resulted in subsequent penetration of the nail into the hip joint or the acetabulum. The six remaining poor results were failures, in most instances, for reasons other than the fractures. One patient had rheumatoid arthritis and was confined to a wheel chair. One had metastatic carcinoma. Others had advanced senile dementia and, in spite of good clinical results from the fracture treatment, simply refused to attempt to walk.

Disregarding other factors, of the fifty patients followed, thirty-seven (74 per cent.) had excellent results from the standpoint of good anatomical restoration by roentgenogram, and normal, or nearly normal, motion of the affected hip and knee.

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PAGET'S DISEASE

A Statistical Study of Eighty-Two Cases *

BY FRANK W. NEWMAN, M.D., PHILADELPHIA, PENNSYLVANIA

A review of the case records at the Hospital of the University of Pennsylvania for the fifteen-year period between 1931 and 1945 revealed eighty-two cases of Paget's disease in a total of about 127,000 histories, or an incidence of between 0.06 and 0.07 per cent. Forty-six cases, or 56 per cent., were admitted as medical cases; the remaining 44 per cent. were admitted as surgical cases.

INCIDENCE

Sex and Age

The incidence of the disease shows an almost equal distribution between men and women,—thirty-nine men and forty-three women. The age incidence is shown in Table I, which illustrates and corroborates the well-known fact that Paget's disease occurs predominantly in late middle life. In only three of the cases in this series was the onset within the first four decades of life. The youngest patient was a woman, twenty-one years of age, whose clinical picture was confused by the presence of syphilitic osteitis.

TABLE I

Age at Onset of Symptoms

Years	Number of Patients
Under 40	3
40 to 49	9
50 to 59	21
60 to 69	29
70 and over	20
Total	82

Familial Incidence

None of the patients in this series gave an authentic history of Paget's disease in either the parents or the grandparents. There was, however, one patient whose sister had a large head and may be presumed to have had Paget's disease, although her record is not included here.

Special attention was paid to the incidence of diabetes mellitus, gigantism, and hyperparathyroidism in the family histories. Four patients had family histories of diabetes, but no cases either of gigantism or of hyperparathyroidism were reported in the families of these patients.

CLINICAL FINDINGS

Chief Complaint

Patients with Paget's disease are often not aware of the disease for many years, and their admission to hospitals is often due to unrelated conditions. In this series, only twenty-nine patients entered hospitals because of pain in a part of the body where the bones were found to show pagetoid changes. Two patients complained chiefly of deformity, and eight others had chief complaints related to cranial nerves in areas found

* Read at the meeting of the Philadelphia Orthopaedic Club, March 14, 1946.

TABLE II

CHIEF COMPLAINTS ON ADMISSION

Symptoms	Number of Patients
Pain in the affected bones	29
Visual or auditory disturbances	8
Cardiac disease	6
Epigastric distress or gastro-intestinal disease	6
Urinary-tract disease	4
Diabetes mellitus	2
Bone deformities	2
Other conditions	25
Total	82

to have pagetoid changes. Thus we have a total of only thirty-nine patients, or less than 48 per cent. of the cases, whose chief complaints were closely related to the existing Paget's disease.

In the remaining 52 per cent. of the cases, Paget's disease was an incidental finding. Of this group, there were six patients whose chief complaint was a cardiac condition, six with epigastric distress or gastro-intestinal disease, four with primary urological problems, and two with diabetes (Table II).

Bones Involved

Twelve patients, like those described by Groh, were found to have only one bony structure involved. (The lumbar spine is considered to be "one bony structure" and so is the pelvis.) The pelvis was involved in twenty-nine cases, the skull in twenty-five, the spine in sixteen, the femur in seventeen, the tibia in seven, the humerus in two, and the radius, fibula, and metacarpals each in one case (Table III).

TABLE III

BONES AFFECTED BY PAGET'S DISEASE

Location	Number
Pelvis	29
Skull	25
Spine	16
Femur	17
Tibia	7
Humerus	2
Radius	1
Fibula	1
Metacarpals	1

LABORATORY FINDINGS

Calcium and Phosphorus Levels in Blood Serum: In thirty-six of the patients the calcium and phosphorus in the blood serum were determined. The calcium ranged from 9.4 milligrams to 12.2 milligrams per 100 cubic centimeters. The phosphorus levels ranged from 2.6 milligrams to 6.75 milligrams per 100 cubic centimeters. This is in accord with the findings of Sugarbaker and of Gutman, Tyson, and Gutman, who have stated that the values of serum calcium and phosphorus are rarely disturbed in Paget's disease.

Serum-Phosphatase Levels: Serum-phosphatase levels varied from a low normal of 0.8 Bodansky units to a high of 175 units. Acid-phosphatase levels varied from a normal low of 0.1 unit to 2.0 units; alkaline-phosphatase levels varied from a low normal of 2.6 units to 48.8 units. Although the alkaline-phosphatase determination was made in only nine cases of the present series, a definite elevation was demonstrated in six cases. This test is, therefore, considered the most useful of all laboratory procedures[5,6] in current use in this institution for making the diagnosis of Paget's disease.

Roentgenographic Findings: In almost every case of this series the diagnosis was made on the basis of roentgenographic findings, which were usually described as "coarse trabeculations, osteoblastic lesions, osteolytic lesions, thickening of the cortex, new-bone production, bone destruction, cotton-wool appearance, marked degenerative changes, and areas of increased or decreased density". Often the roentgenologist assumed a familiarity with the typical appearance of the disease and merely stated that the bones showed pagetoid changes. The conditions with which the diagnosis may be most easily confused are metastatic new growths, particularly metastases from the cancerous prostate[11,13].

FIG. 1-A

Case 2, Mrs. E. S. Roentgenograms show Paget's disease of tibia, undergoing sarcomatous degeneration.

TABLE IV

BONES IN WHICH FRACTURES OCCURRED

Location	Number
Femur	9
Humerus	4
Tibia	2
Pelvis	2
Radius	1

COMPLICATIONS

The complications of Paget's disease, in the order of their frequency in this series, are as follows: (1) cranial-nerve pressure, (2) fractures, (3) urinary calculi, and (4) sarcomatous degeneration.

Cranial-Nerve Pressure: Twenty-two patients, or 26.8 per cent. of the total number, had defective visual or auditory apparatus. Twenty of these patients had auditory difficulties and two had visual disturbances. Before making any final conclusions as to the etiology of these eye and ear conditions, it would be necessary to have the help of ophthalmologists and otologists in ruling out those due to arteriosclerosis and other causes.

Fractures: Fractures occurred in fifteen patients, or 18.3 per cent. of the total (Table IV). At least nine were pathological,—that is, fractures through bone which, because of Paget's disease, had less than normal strength. From the records available[9], it appears that only one of the fractures failed to unite within a reasonable period of time.

Urinary Calculi: Whether or not calculi in the urinary tract should be considered a complication of Paget's disease is debatable[3]. In the present series this condition occurred in four patients, an incidence of 4.9 per cent.

Sarcoma: The incidence of osteogenic sarcoma or chondrosarcoma in Paget's disease

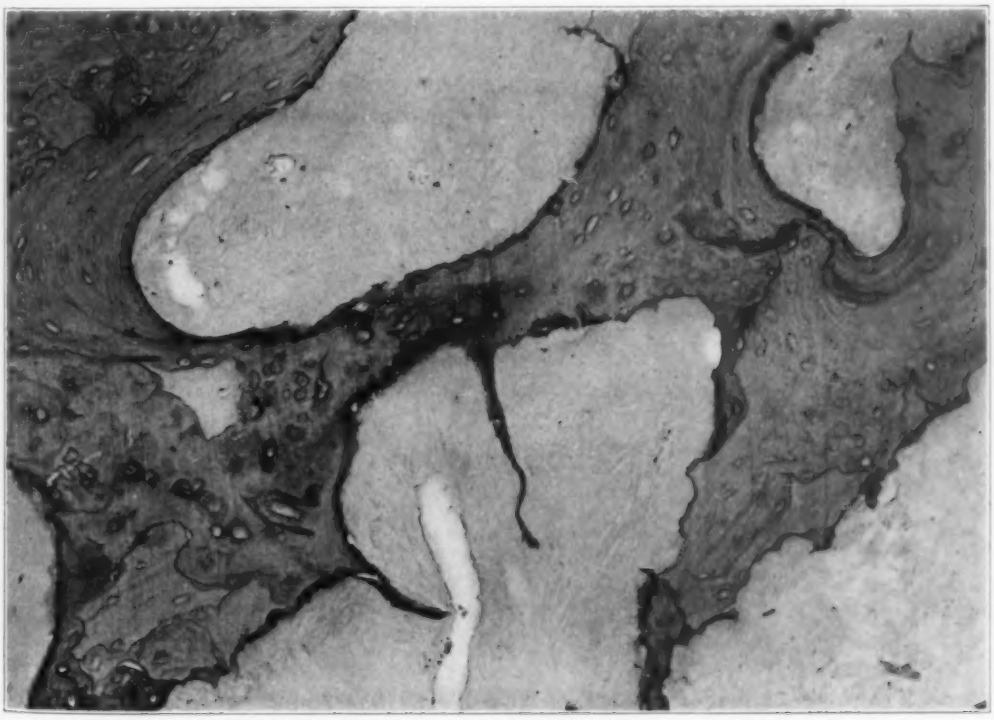

FIG. 1-B

Photomicrograph of biopsy specimen of tibia (×125). Shows bone changes typical of Paget's disease.

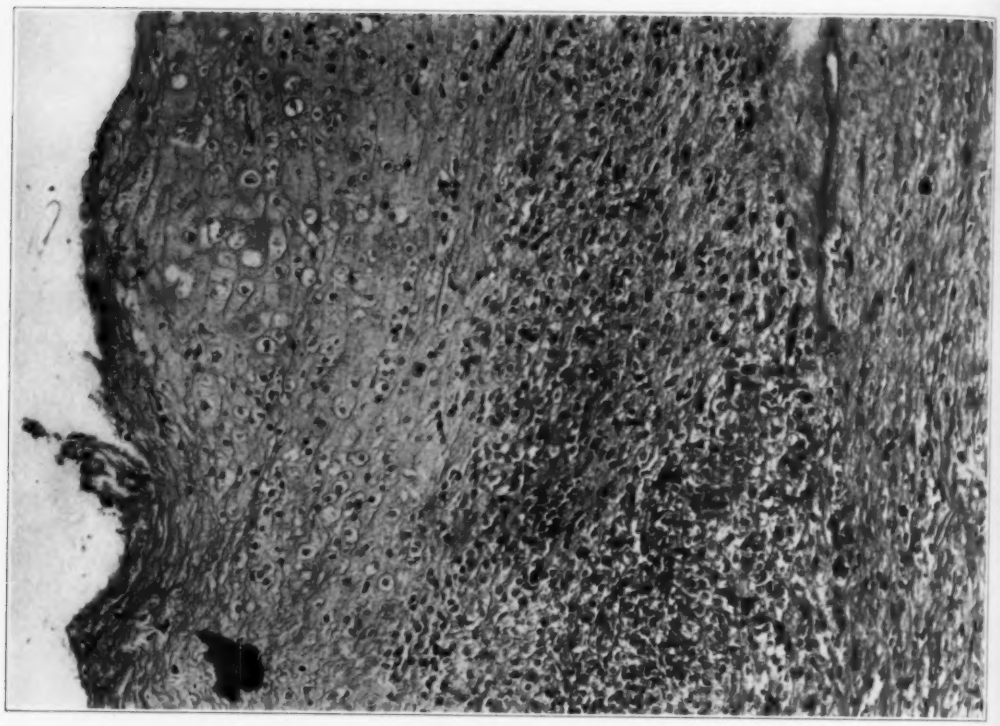

FIG. 1-C

Photomicrograph of biopsy specimen (×100). Shows chondrosarcoma.

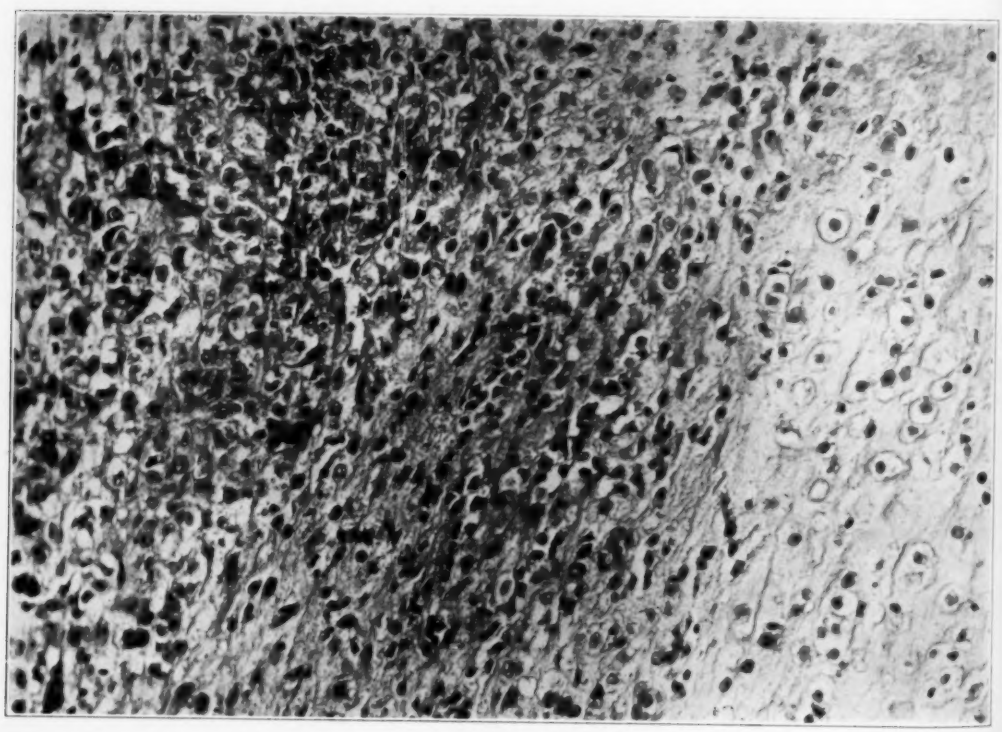

FIG. 1-D

Photomicrograph of biopsy specimen (×242). Shows chondrosarcoma.

is usually said to be about 7 per cent.[1,8]. The incidence in the present series is considerably lower. There were only two cases of proved sarcoma, or 2.4 per cent. A brief résumé of these two case histories follows.

CASE 1. Mrs. J. D. was a white woman, fifty-three years old, who came to the Hospital complaining that a painful swelling of the right knee had persisted for three or four months. She had noted no redness or local heat, and had no systemic reaction. Before studies were completed, she went to another hospital, where a diagnosis of chondrosarcoma was made and the extremity was amputated. Microscopic study of the amputated specimen confirmed the diagnosis of Paget's disease with superimposed chondrosarcoma. The patient remained free from further complaints until about eleven months after operation, when a persistent cough again brought her to this Hospital. Roentgenograms at this time revealed metastases in the lungs. Eight months later the patient died. Survival after amputation was about twenty months. No autopsy was done.

CASE 2. Mrs. E. S. was a white woman, seventy-three years old, who came to the Hospital complaining of a painful swelling of the left leg, just below the knee, which had been present for six or seven months. Roentgenograms were reported as showing "typical changes of Paget's disease in the upper half of the left tibia". Because of the severe pain and the rapidity of onset, a biopsy was done; a diagnosis of Paget's disease with chondrosarcoma was made. The patient refused operation at that time, but has since had the extremity amputated at another hospital. It is now three months since the operation, and the patient has had no further complaints.

THERAPY

Inasmuch as it is the complications and sequelae of Paget's disease which usually cause the patient to seek medical care, treatment has usually been directed toward relief of the presenting symptoms. Auditory and visual disturbances are referred to ophthalmologists and otologists. Fractures have been treated by orthopaedic surgeons and general surgeons, who use standard methods; prognosis as to union is considered to be good[9,10]. Sarcomata have been treated by early amputation whenever possible. Roentgenotherapy is usually used when amputation is refused or is impossible, but not many roentgenologists consider it the method of choice. If one may judge from the present small series, even amputation must be followed by an unfavorable prognosis.

Therapy directed toward relief of symptoms caused by the disease *per se* has in the past been of many kinds, of which only two will be mentioned,—namely, roentgenotherapy and magnesium carbonate.

Roentgenotherapy was given to two patients in this series, both of whom complained of hissing sounds in the ears. Both were given two courses of treatment and were still not improved ten or twelve months afterward. Formerly this method was used to relieve pain in bones showing pagetoid changes, but in the last five years there have been almost no references to it in the medical literature.

Magnesium carbonate was given by mouth to eight patients, six of whom showed symptomatic improvement within one or two months. The dose recommended was usually one teaspoonful of the powder two or three times daily, unless the stools became too loose, in which case the dose was decreased to an amount which could be tolerated[2]. Concurrently, a diet low in calcium was recommended. The patients who benefited from this regimen found that their complaints were minimum while they conscientiously followed instructions as to medication and diet, but they also noted that their symptoms returned within a few days if they abandoned the regimen.

NOTE: The author gratefully acknowledges permission to use case histories from the Medical Service of O. H. P. Pepper, M.D., and from the Surgical Services of I. S. Ravdin, M.D., Francis C. Grant, M.D., P. Boland Hughes, M.D., and P. C. Colonna, M.D.

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POSTERIOR APPROACH TO THE SUPEROLATERAL REGION OF THE TIBIA

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Occasionally bone lesions are found in the lateral tuberosity of the tibia or very high in the posterolateral aspect of the tibia. The surgical access to this area is difficult, and the customary procedure includes a temporary resection of the proximal end of the fibula. Fiolle and Delmas described in detail an approach to the origin of the anterior tibial artery, in which the steps of the temporary resection of the distal end of the fibula are described with simplicity and clarity.

Darrach gave a good description of an approach to the posterior aspect of the tibia and the popliteal space, but he was interested primarily in the blood vessels and nerves. Harmon presented a simplified exposure of the posterior region of the tibia for bone-grafting, but specified that the upper fifth of the tibia was not included. Cadenat's anatomical and surgical study of the approaches to the upper and lower extremities gave an all-embracing survey of the entire problem.

The purpose of this article is to present an approach to the bony structures of the upper posterolateral aspect of the tibia. The procedure proved to be useful in several cases, and may be of help to surgeons who are confronted with similar problems.

The anatomy of the area through which the penetration to the bone is obtained was analyzed in thirty cadavera. To complete the description of the surgical approach, discussion of the most common variations of surgical interest is included. With this in view, the following analyses were made:

1. Disposition of the superficial nerves for orientation.
2. Relation of the muscular nerve branches to the muscles of the region and to the tibial and common peroneal nerves.
3. Relation of the origin of the anterior tibial and peroneal arteries to the angle between the tibia and fibula.
4. Variations in the relation of the large vessels to the ring of the soleus.

The arrangement of motor and sensory nerve branches and of the vessels of the popliteal space is such that it can be utilized with profit in the surgery of this region. There are no important nerve branches to the medial side of the popliteal neurovascular bundle between the femoral part of the medial head of the gastrocnemius and the origin of the tibialis posterior on the tibia. Only one small artery crosses this region,—namely, the medial inferior genicular.

A dry, safe field, with exposure of the popliteus, can be obtained if a longitudinal incision is made, penetrating the popliteal region on the medial side of the popliteal artery, and the medial inferior genicular artery is divided and ligated. The popliteus can be divided to expose the underlying bone. With this procedure, the exposure of the upper end of the tibia can be accomplished in a few steps.

DESCRIPTION OF PROCEDURE

A longitudinal incision, four or five inches long, is made in the mid-line, crossing the transverse popliteal crease. The fascia is exposed and the short saphenous vein is identified in the middle of the field, piercing the fascia. To the lateral side of the short saphenous vein, the medial sural cutaneous nerve can be seen through the fascia. The nerve is approximately parallel to the vein. Medial to the vein runs the terminal part of the posterior femoral cutaneous nerve. An incision is now made at the medial side of the posterior femoral cutaneous nerve and the short saphenous vein (Fig. 1).

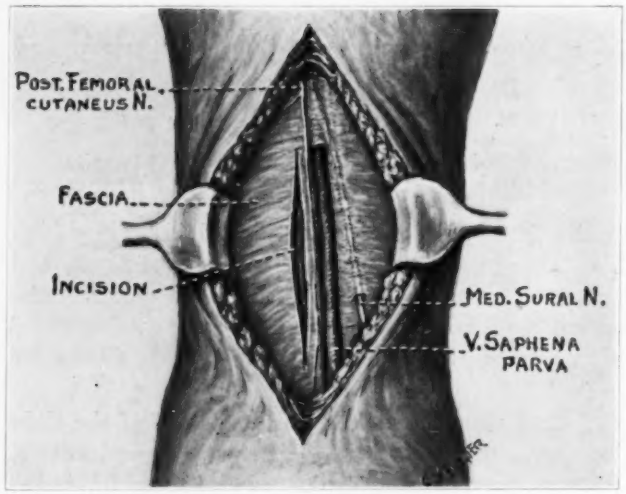

FIG. 1

The sural and the posterior femoral cutaneous nerves help in the orientation of the incision through the fascia. The variations of the posterior femoral cutaneous nerve consist mostly in its termination at points higher or lower than the articular line, or in its breaking up into multiple filaments. The medial sural nerve is sometimes found on the medial side of the short saphenous vein.

The division of the fascia, and its retraction to the sides, exposes the angle of fusion of the medial and lateral heads of the gastrocnemius, which form the distal angle of the popliteal rhombus. The angle of fusion of the heads of the gastrocnemius is divided distally. Retraction of the heads of the gastrocnemius uncovers the shiny long tendon of the plantaris, which indicates the position of the ring of the soleus and, roughly, the line of origin of the soleus on the tibia. Gentle blunt separation locates the popliteal artery as it enters the ring of the soleus. The oblique fibers of the popliteus are visible deep to the artery. On the surface of the popliteus, one can observe the medial inferior genicular artery with its venae comitantes, on its way to the medial aspect of the knee (Fig. 2).

The medial inferior genicular artery is fairly constant in its course. Occasionally it may be found above the popliteus, and infrequently it consists of two trunks instead of one.

Up to the present step, not a single important nerve twig has been encountered in the operative field. The motor nerve twigs to the medial head of the gastrocnemius are never low enongh to interfere with the proximal end of the exposure. The twigs to the soleus are lateral to the popliteal artery. The nerve branches to the upper end of the origin of the tibialis posterior are too low to interfere with the distal end of the incision.

The next step consists in retracting the popliteal artery in a lateral direction and in separating the line of origin of the soleus from the tibia. This is accomplished with great ease with a blunt periosteal elevator. The disinsertion of the soleus, medial to its ring, permits wide lateral retraction of the soleus with the artery, vein, and tibial nerve. The medial inferior genicular artery and veins are divided and ligated. The popliteus is divided across its fibers, stripped from the tibia, and retracted in a lateral direction (Fig. 3).

Although the popliteal artery is not exposed completely when it is identified in this dissection, it is important to be aware of the possible variations which may be encountered in the region. The popliteal artery may divide into its branches near the superior border of the popliteus. Under these circumstances, the posterior and anterior tibial arteries may both lie on the posterior surface of the popliteus, or the anterior tibial artery may pass in front of the popliteus and the posterior tibial artery may pass on the posterior surface of the same muscle. The posterior tibial artery may vary in size and, on rare occasions, may be much smaller than usually represented. However, the variations in the division and size of the popliteal artery do not modify the steps of the approach, if the popliteus is divided on the medial side of the artery and the muscle is separated gently from the underlying tibia.

The retractor which is introduced under the lateral edge of incision of the popliteus after its division produces traction and simultaneously protects the large vessels and the important nerves, which are all located lateral to the incision.

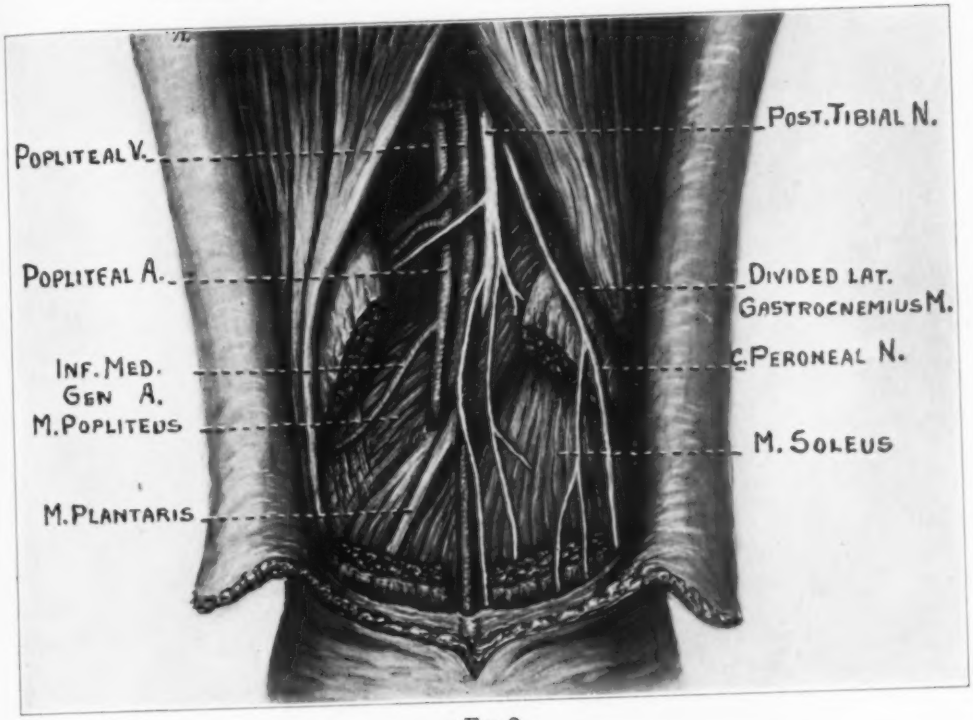

FIG. 2

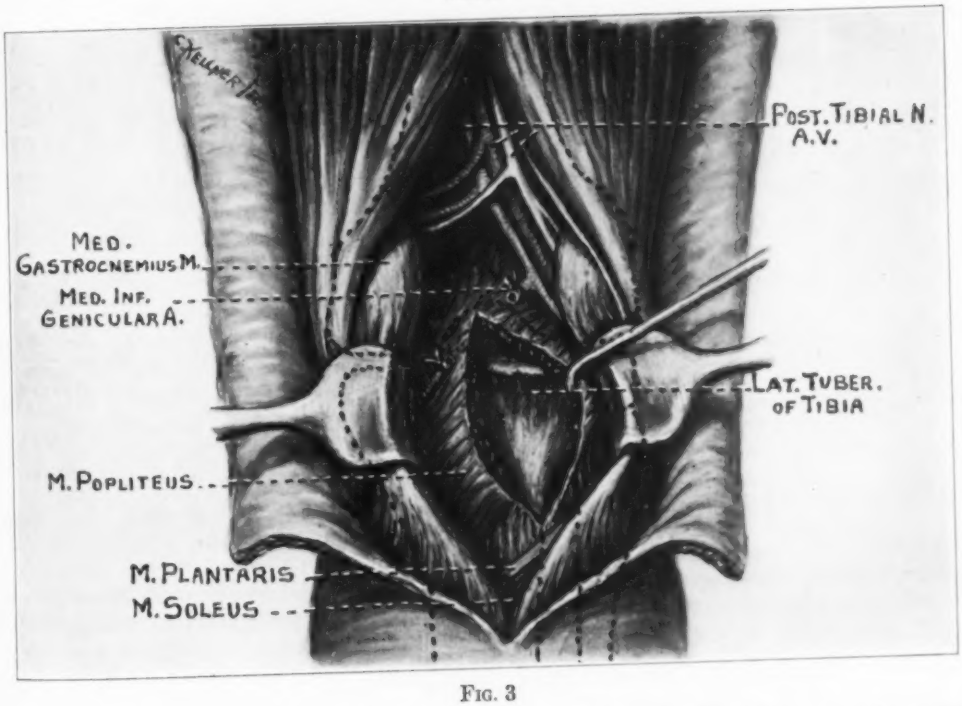

FIG. 3

The angle formed by the tibia and the upper end of the fibula can also be exposed. The anterior tibial artery originates in this area and must be avoided. It has been found that the anterior tibial artery almost never passes through the interosseous membrane at the apex of the angle formed by the tibia and fibula. The distance between the apex of the angle and the artery varies from approximately 2.5 to 4.5 centimeters. This relationship permits ample room for approach to the tibiofibular angle.

FIG. 4-A

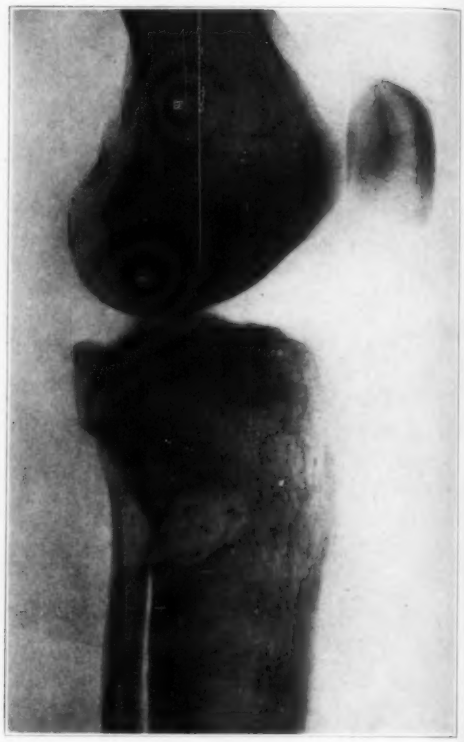

FIG. 4-B

Postoperative roentgenograms show bone defect at site of previous osteoma.

Upon completion of the operation, the structures are permitted to fall back into place. The fascia is the only structure which requires suturing.

The advantages of the procedure described may be summarized as follows:

1. Temporary resection of the fibula is avoided;
2. There is only slight interference with anatomical structures;
3. The postoperative closure is simplified, because only suture of the fascia is required.

The only disadvantage of this approach is the relative depth of the operative field. The position of the fibula, in a more posterior plane than the tibia, restricts somewhat the lateral retraction, but this does not interfere with proper exposure of the field.

ILLUSTRATIVE CASE

H. K., thirty-two years old, was admitted to the Hospital on September 18, 1945, complaining of pain in the anterolateral region of the left knee of three years' duration. Roentgenographic examination suggested an osteoid osteoma of the upper posterolateral region of the tibia. The lesion was excised on September 22, 1945, under roentgenographic control, through the posterior approach already described. Postoperative roentgenograms showed a bone defect, corresponding to the site of the osteoma (Figs. 4-A and 4-B). The patient made an uneventful recovery and resumed his normal activities in one month.

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A SURGICAL PROCEDURE FOR REPAIR OF RECURRENT DISLOCATION OF THE SHOULDER JOINT

A Preliminary Report *

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In the United States Navy during World War II, it was found that recurrent dislocation of the shoulder was encountered more frequently than in civilian practice, and that it made the sailor or marine unfit for full combat duty. The frequent failure of the usual methods of surgical treatment for recurrent dislocation of the shoulder led to a study of the literature and the development of a new operative procedure.

Chronic dislocation of the shoulder produces apprehension in a sailor or marine, because the shoulder may become dislocated at any time, causing pain and complete disability. In some cases, the individual is able to reduce the dislocation himself; but, in jungle warfare, even temporary disability may be fatal. The soldier with such a disability is unfit for full combat duty.

The many operations described in the literature for repair of recurrent dislocation of the shoulder can be classified into three groups: (1) operations altering the skeletal structure of the shoulder joint, using bone graft to augment the anterior rim of the glenoid cavity, or so placed as to prevent the humeral head from leaving the glenoid fossa; (2) operations on the capsule of the shoulder joint, either repairing injury to the capsule or adding fascia to supplement the capsule; and (3) ligamentous, tendon, or muscle suspensions.

In the first group of operative procedures, the skeletal structure of the shoulder joint is altered. In the second group, the torn capsule of the joint is repaired, either by plicating the capsule or by adding fascial transplants to strengthen the capsule. In the third group of operative procedures, either the anatomical relation of ligaments, tendons, or muscles already present in the shoulder girdle is altered, or such tissues are transplanted to the shoulder to suspend the humeral head in the glenoid cavity.

The treatment for recurrent dislocation of the shoulder at a Naval Hospital is influenced by many factors which do not disturb the civilian surgeon. If the condition existed prior to enlistment, no operative procedure is warranted unless it will return the man to full duty. A physical defect is often used as an excuse to avoid duty, and an operation done while the man is in the Service may supply the necessary objective condition which is desired by the patient. If the injury is acquired in the Service, the malingering element is reduced.

The author performed a series of fourteen operations on thirteen patients for the repair of recurrent dislocation of the shoulder, by a technique not previously described. This technique used a three-inch incision over the bicipital groove, separating the anterior deltoid muscle. The transverse humeral ligament was cut, and the tendon of the long head of the biceps was retracted with a tape. The cartilage on the floor of the groove was removed, the synovial membrane on the tendon was cut away, and the tendon was anchored in the bicipital groove with three No. 3 nylon sutures, passed through holes drilled in the posterior crest of the groove. The transverse humeral ligament and the outer edge of the tendinous capsular cuff were closed. When possible, the capsular cuff was plicated with No. 3 nylon sutures. Exercises were started and increased according to tolerance, after three weeks' immobilization of the affected shoulder in a sling and a bandage. Five of the

* Based on a scientific exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1946.

FIG. 1

FIG. 2

FIG. 3

Fig. 1: Front view, showing the origin of the tendon of the long head of the biceps, changed from the supraglenoid tubercle to the acromion. The tendon passes out of the joint through a hole cut in the anterosuperior capsule.

Fig. 2: Side view, showing the origin of the tendon of the long head of the biceps, changed from the supraglenoid tubercle to the acromion. The tendon passes in a straight line from the proximal end of the intertuber groove of the humerus to the acromion.

Fig. 3: Sagittal section through the shoulder at the level of the tendon of the long head of the biceps, showing how changing the origin from the supraglenoid tubercle to the acromion prevents dislocation of the shoulder.

patients in this series (including one case which was bilateral) returned to active duty with the Fleet Marine Force in the Pacific; four were returned to limited duty; and four had a recurrence of the dislocation after the operation. The author performed the second operation on the four patients with recurrences. At the second operation, the tendon of the long head of the biceps muscle was found to be firmly anchored in the bicipital groove, and the tendon was intact. At this operation, a transverse hole was drilled through the greater tuberosity, and a hole was placed in the acromion from above downward. Fascia lata was passed through these holes, drawn tightly, close to the capsule, and sutured to itself and to the capsule. The fascia was spread over the anterior capsule and was sutured to strengthen the capsule. Six to ten months have passed since the second operation, and at the present time the shoulders are secure and solid, with practically normal motion.

It was felt that the procedure of anchoring the tendon of the long head of the biceps in the bicipital groove was sufficient for normal civilian function, especially in individuals beyond the age of active athletics, and that this procedure was preferable to other operations because of its simplicity. However, the operation did not give sufficient strength to

the shoulder to permit all patients to return to the strenuous activity of the Fleet Marine Force. Consequently, the following operation was performed on thirty-two shoulders with recurrent dislocations (two patients had bilateral recurrent dislocations), and has fulfilled all requirements.

OPERATIVE TECHNIQUE

1. A longitudinal incision is made from just above and medial to the tip of the acromion process, downward about four inches toward the mid-cubital fossa of the elbow. The fibers of the anterior deltoid muscle are separated to expose the capsule of the shoulder joint and the transverse humeral ligament.

2. The capsule is cut from a point just above the upper end of the bicipital groove, medially and slightly upward over the course of the biceps tendon for a distance of three-quarters of an inch. When the capsule is opened with retractors and the arm is pulled downward, the superior part of the joint is exposed, showing the origin of the long head of the biceps tendon at the supraglenoid tuberosity. A tape is placed under the tendon for the purpose of traction.

3. The tendon is cut close to its origin from the supraglenoid tubercle, causing little or no bleeding, and the cut end is removed from the joint.

4. Lateral traction on the freed tendon exposes the cartilage on the floor of the bicipital groove. This is removed with a sharp curette. The tendon is pulled upward and its synovial membrane is removed from that part of the tendon which passes through the bicipital groove.

5. The free end of the tendon is passed through a small hole cut in the superior part of the capsule, and carried under the deltoid muscle to the acromion process in as nearly a straight line as possible (Figs. 1 and 2).

6. The superior surface of the acromion is exposed, and a hole, large enough to receive the free end of the biceps tendon, is made through it from above downward. The hole is placed about one-quarter of an inch from the edge of the acromion so that a strong bridge of bone remains. The free end of the tendon is passed through this hole from below upward, and about one-half inch of the tendon is allowed to extend beyond the acromion. The end of the tendon is divided so that the anterior half can be brought forward and downward, and can be sutured to the trunk of the tendon just before it enters the hole in the acromion. The posterior half of the divided tendon end is carried backward and sutured to the periosteum of the acromion (Fig. 3). The elbow is flexed and the arm abducted during this step, so that there is very little tension on the biceps tendon.

7. The incision through the capsule, which parallels the superior margin of the subscapularis tendon as it merges into the capsule, is plicated with a double row of interrupted No. 1 nylon sutures.

8. The tendon is anchored in the bicipital groove by a deep No. 1 nylon suture, passed through the transverse humeral ligament, incorporating the biceps tendon.

9. The shoulder joint is passed through its complete range of motion to ensure adequate fixation of the tendon and the plicated capsule. The deep sutures over the acromion are placed through the tendon so that fixation of the tendon is made firm, and the wound is closed anatomically.

10. The shoulder is immobilized in a sling and a modified Sayre's bandage for three weeks.

11. After the three weeks of immobilization, gradually increased exercises are begun.

SUMMARY OF CASES

Operations were performed in thirty-two cases,—thirty men and two women. Their ages ranged between eighteen years and thirty-four years. Twelve dislocations occurred in the right shoulder; sixteen occurred in the left shoulder; and two were bilateral. In

eight cases the first dislocation occurred during combat fighting, in thirteen while engaged in athletics, in seven from a fall, and in one while rolling a barrel; in three cases the cause was not remembered. The treatment after the first dislocation varied: No treatment was given in fifteen cases, a sling was used for less than three weeks in twelve cases and for three weeks or more in four cases, and treatment was not remembered in one case. Preoperative examination of the shoulder showed limited and painful motion in thirteen cases, muscle atrophy about the shoulder in three, and subluxation of the joint in ten; all had deep tenderness over the front of the shoulder joint. Roentgenographic findings were negative in twenty-four cases, showed subluxation in three, calcium deposits in the subdeltoid bursa in one, a shallow glenoid fossa in one, a groove in the head of the humerus in one, roughness of the anterior glenoid rim in one, and roughness in the greater tuberosity and acromion in one.

All of the operations except one were done on Marine personnel. Eight cases have been followed for more than one year; the remaining cases have been followed for more than six months. In one case in the series, the operation failed, because the new attachment of the tendon pulled away from the acromion when the patient threw a football, four weeks after operation. In twenty-seven of the remaining thirty cases, the patients returned to full combat duty. The other three patients could not return to full duty, although the shoulder was stable. Follow-up letters have been received from two of the three patients, stating that they are doing heavy work without discomfort. In the remaining case there has been no further dislocation, and a follow-up letter from the patient's mother states that he does not want to work.

COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT

The Nature of the Traumatic Lesion and Effective Methods of Treatment with an Analysis of Forty-One Cases

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Although incomplete dislocations of the acromioclavicular joint are frequent, complete dislocations are uncommon, and even orthopaedic surgeons of wide experience seldom see very many cases in their personal practices. The largest single series on record consists of less than a dozen cases. The lack of large single experiences may reasonably be assumed to account for a number of facts: that the pathological basis of complete dislocation of the acromioclavicular joint is still incompletely understood; that in spite of the small number of recorded cases, more than thirty-five conservative methods and at least twenty-eight operative methods of correction have been advocated; and that very few end results of treatment by any measures are recorded in the literature.

The existing situation in respect to complete dislocations of the acromioclavicular joint is the justification for the present communication, which has for its purpose (1) the presentation of forty-one patients treated by a single observer, this apparently being the largest single series to be recorded; (2) clarification of the anatomicopathological basis of the lesion; (3) an evaluation of the conservative and operative methods currently advised for the correction of the dislocation; and (4) the description of an improved method of conservative treatment.

ANALYSIS OF CASES

The forty-one instances of complete dislocation of the acromioclavicular joint reported in this communication were observed in the 802nd Hospital Center while it was stationed at Blanford, England, and at the 97th General Hospital while it was stationed at Frankfurt, Germany. The series does not include primary subluxations or sprains. All patients with minor subluxations, observed in the European Theater of Operations, were treated in forward medical units or hospitals and could return to duty within a month, the results apparently being in agreement with those obtained by Thorndike and Quigley with various types of strappings. The evidence is to the effect that sprains, if left alone, become reduced spontaneously within a week or less, and heal well.

All the patients were strong, active young soldiers, within the same age group. Their injuries, all of which were caused by great violence, were variously sustained in combat, parachute jumps, hazardous engineering operations, and traffic accidents; a few were sustained on the football field. Twenty-three injuries were acute and were recognized early. As a result, the patients were promptly evacuated from the combat zone and arrived in fixed hospitals for treatment within a few hours after injury, if transportation was by air, and within ten days, if transportation was by water or by rail. The majority had received first aid or primary treatment shortly after the injury. In the remaining eighteen cases, the injury was unreported, unrecognized, or untreated for periods ranging from several weeks to eighteen months after it had occurred. In this group of cases the orthopaedic problem was often complicated by such war-related conditions as combat fatigue and conversion reactions, focused upon non-disabling and non-symptomatic lesions. Eleven patients, representing both groups, had associated fractures of various portions of the clavicle, the acromion process, and the coracoid process.

ANATOMICAL STRUCTURE AND POSSIBLE VARIATIONS OF THE ACROMIOCLAVICULAR JOINT

The acromioclavicular joint, which overlies the shoulder joint and the motion of which is synchronous with the motion of the shoulder joint, appears to be unique in man. The

relationship between the structures which make it up—the clavicle and the acromion process—is normally maintained by the acromioclavicular and coracoclavicular ligaments. The coracoclavicular ligaments form a synosteosis of a particular type termed syndesmosis which indicates that the skeletel elements are bound together by a continuous band of elastic connective tissue. Anatomical studies of the shoulder area, as well as numerous reports of anomalous conditions in this region, show that the coracoclavicular syndesmosis either is a metamorphosed joint or represents a trend toward the development of a diarthrodial joint between the coracoid process and the inferior surface of the clavicle. About 1 per cent. of random roentgenograms of the shoulder[54,57] show well-developed coracoclavicular diarthrodial joints. The acromioclavicular joint itself is a true diarthrosis, because the articular surfaces of the acromion process and the outer end of the clavicle are separated by a joint cavity and are surrounded by a capsule reinforced with ligaments. Since in man there is no motion of the coraco-acromial syndesmosis (represented by the coraco-acromial ligament), its functional significance is not clear. It can be sacrificed without any effect on the action of the shoulder[13].

The possible variations in the form of the acromioclavicular joint were studied in 100 sample roentgenograms of the shoulder, which were unselected except that the patients had no symptoms referable to the shoulder and that the variations were present bilaterally. All films were taken by the standard Army method, so that variations cannot be explained by changes in technique. The formal study of these sample films was undertaken to confirm the impression of the frequency of variations which the writer had received as he examined large numbers of films for other orthopaedic conditions.

TABLE I

CLASSIFICATION OF ANATOMICAL VARIATIONS IN THE ACROMIOCLAVICULAR JOINT IN 100 RANDOM ROENTGENOGRAMS OF THE SHOULDER

	Description of Joint	Per Cent.
1.	The articular surface of the clavicle overrides the articular surface of the acromion.	49
2.	The articular surfaces of the acromion and clavicle are nearly vertical and lie in the same plane.	27
3.	The inferior margin of the articular surface of the clavicle underrides the superior margin of the acromion.	3
4.	The articular surfaces are incongruent, and the clavicle overlies the acromion.	9
5.	The articular surfaces are incongruent and are not in contact at any point.	6
6.	The articular surfaces are incongruent, and the inferior margin of the clavicle underrides the superior margin of the acromion.	6

From this study the following facts were ascertained: The articular surfaces vary in size and form. Occasionally they are separated by a meniscus attached to the superior acromioclavicular ligament. The meniscus may be a blade of fibrocartilage extending perhaps halfway into the joint (as in Case 36) or it may form a complete disc, dividing the joint into two parts. Occasionally no diarthrosis is present, as in Case 39 of this series, in which the joint was represented merely by a pad of fibrous tissue attached to the outer end of the clavicle, and no evidence of an articular cavity was noted. Such instances are described in standard texts of anatomy[72] and are not uncommon.

The joint surfaces are often incongruent, such abnormalities almost always being bilateral. The outline of the articular surface of the acromion process may correspond to the outline of the clavicle, but often it does not. In some individuals no part of the clavicle opposes the end of the acromion, and for all practical clinical purposes the patient has a congenital subluxation or relaxation of the acromioclavicular joint. The clinical prominence of the acromioclavicular joint is usually determined by the degree of overriding of the acromial end of the clavicle. In some individuals, the joint surfaces may lie in a vertical plane (Fig. 3) or the acromion may partly overlie the clavicle (Fig. 7), although in the majority of cases there is usually some overriding of the clavicle on the acromion

(Fig. 10). These and other variations observed in the 100 cases studied roentgenographically are classified in Table I. In addition to this classification, the acromioclavicular joint can vary in the shape of the distal end of the clavicle, which may be bulbous, square, fusiform, flattened, or cylindrical.

As this study indicates, relatively seldom does the acromioclavicular joint, as observed roentgenographically, correspond to the classical anatomical description. Normally the articulation is constructed of parts, formed at different stages of the morphogenesis of the typical diarthrosis. There is some evidence, although the observation is still disputed, that the outer end of the clavicle is formed in the embryo by intramembranous ossification[90]. Be this as it may, variations from the anatomical norm are reasonably accounted for by the fact that the evolutionary development of the acromioclavicular joint was frequently interrupted.

MECHANISM OF INJURY AND THE TRAUMATIC LESION

With few exceptions, the patients in this series were unable to state at just what point the shoulder had received the blow which resulted in acromioclavicular dislocation. Only two had abrasions or ecchymosis to indicate the point of contact of the force,—in Case 36 a falling steel beam struck the acromion process, and in Case 40 the area over a fracture of the clavicle was discolored. In the majority of cases, it was assumed that a blow on the dorsum or the anterior aspect of the shoulder had forced the scapula downward or backward[13,74,89]. Cases have been recorded in which the scapula was forcibly drawn downward and anteriorly by a sudden change in the position of a heavy burden being carried[54], and others are on record in which the force may have been transmitted through the arm, with the result that the coracoid process came into contact with the clavicle and thus pried the joint apart[54,100].

It has been generally assumed, since the pioneer surgical work of Cadenat in 1917 and of Watkins in 1925, that a complete dislocation of the clavicle cannot occur without tearing of the conoid and trapezoid ligaments[1,9,54,62,85], and illustrations in current textbooks[49,83,86] are based on this concept. There is, however, very little evidence in the literature to support it[62,98]. It is easily understood that, when the distance between the coracoid process and the clavicle is greatly increased in the injured shoulder, as compared with the intact shoulder, the coracoclavicular ligaments are correspondingly stretched or sprained, but they are not necessarily torn[57]. If the force was transmitted through the arm, the injury might be sustained by the joint capsule alone, the ligaments themselves suffering no damage.

The deformity in unreduced dislocations of the acromioclavicular joint is maintained by the pull of the trapezius on the distal end of the clavicle, by gravity, and by the absence of counterpull by the aponeurosis of the anterior portion of the deltoid. When the arm on the affected side is weighted, the scapula and so the acromion process are drawn downward and forward, causing the gap in the joint to be increased both anteroposteriorly and superoinferiorly. In doubtful cases this manoeuvre is useful in accentuating the lesion for roentgenographic purposes.

EXPERIMENTAL OBSERVATIONS

The following experimental studies were carried out on cadavera to confirm impressions as to the mechanism of injury, derived from observations made at the operating table:

1. On the first shoulder, the coracoclavicular ligaments were transected through a stab incision, after which the acromial end of the clavicle was grasped through the skin with bone forceps and tested for motion. Motion was not in excess of that on the intact opposite side, and subluxation was not produced when strong traction was applied to the arm on the transected side.

2. On the second shoulder, the superior acromioclavicular ligament and the entire

joint capsule were transected through an incision overlying the joint. After this, it was possible to produce incomplete disarticulation of approximately 50 per cent.

The incision was then carried around the outer end of the clavicle in the shape of a U and the attachments of the deltoid and trapezius muscles to the clavicle were divided. When the end of the clavicle was drawn upward and posteriorly, complete disarticulation resulted; but when it was pulled straight upward, only incomplete disarticulation was produced.

Transection of the coracoclavicular ligaments was then performed on the same shoulder, as described under heading No. 1, after which the entire outer end of the clavicle could be disarticulated upward farther than when only the attachments previously mentioned had been cut.

3. On the third shoulder, the trapezoid ligament was dissected and divided, as well as the deltoid and trapezius attachments to the clavicle and the superior acromioclavicular ligaments. The clavicle could then be drawn posteriorly or upward until it was completely dislocated.

4. On the fourth shoulder, the same preparation was carried out as described under heading No. 3, except that the conoid ligament was sectioned instead of the trapezoid. The same results were achieved as on the third shoulder, except that the acromial end of the clavicle could be dislocated farther upward.

5. On the fifth shoulder, the same preparation was carried out as on the third and fourth, except that the coraco-acromial ligament was sectioned, first alone and then in combination with each of the other ligaments. No effect on the stability of the acromioclavicular joint was observed.

Observations similar to those described have been reported by Poirier and Rieffel, Delbet and Mocquot, and Cadenat, among others; and their interpretations of the results are in agreement with that of the writer, except for one important difference: The observations just recorded emphasize the leading role played in complete dislocation of the acromioclavicular joint by the joint capsule and the attachments of the deltoid and trapezius muscles. When these structures were severed, to simulate the tearing or stretching which occurs in them with dislocation, complete dislocation of the outer end of the clavicle was possible without injury to the conoid or trapezoid ligaments. It is true that rupture of the conoid and trapezoid ligaments allowed greater displacement of the clavicle, but the picture was altered quantitively, not essentially. Section of only the conoid or of only the trapezoid ligament had no specific effects, and there is no physiological analogy between these structures and the cruciate ligaments of the knee.

Cadenat reminded his readers that tone and action of the surrounding muscles in the living subject probably alter the relationships of the parts in the functioning joint, and the individual ligaments may have different degrees of elasticity, required for synchronizing the motions of the clavicle with those of the surrounding parts.

EXAMINATION OF RESECTED JOINTS

It was possible to study the process of healing after complete dislocation of the acromioclavicular joint in nine cases in which resection of the distal end of the clavicle was necessary at intervals varying from three weeks to one year after injury. A variety of treatments had been employed in these cases, all of which had resulted in incomplete correction. No fresh clinical material was available for examination, since, in accordance with directives of the United States Army Medical Department, all cases must be managed conservatively and healing must be permitted for a sufficient length of time to establish the existence of a residual disability before surgical treatment is instituted.

In each case the coracoclavicular ligaments were found to be stretched and elongated, but all had healed in complete continuity. The texture upon palpation varied between cicatricial induration and bony hardness. Elongation and scarification were proportional

to the distance between the outer end of the clavicle and the coracoid process, but bony tissue was not always identified.

Healing of the joint capsule in each case had been associated with increased thickening, up to a maximum of four millimeters.

Other changes were as follows: (1) Obliteration of the articular surfaces and replacement with fibrous connective tissue occurred in five cases; interposed flakes of cartilage, fibrocartilage, and necrotic hyalinized material were interpreted as the remnants of capsular ligament and meniscus, separated at injury in two cases. (2) Osteocartilaginous loose bodies were found in one case (Fig. 13). (3) Osteo-arthritic changes, such as bone eburnation and marginal spurs, occurred in five cases. In two cases evidence was found of subchondral compression fractures of the clavicle and acromion processes, which had not been evident in the roentgenograms.

The observations on healed ligaments are corroborated by the findings of Gurd on fresh cases; this author also mentioned that complete dislocation of the clavicle occurred in one case without complete rupture of the coracoclavicular ligaments. Other observers, however, describe stretched[11] or ruptured[16,18] ligaments at open operation for repair of the conoid and trapezoid ligaments with fascia lata.

The data obtained by observation of both clinical and experimental material make it seem most likely that the clavicle can become completely dislocated without rupture of the coracoclavicular ligaments. In occasional cases the trapezoid ligament is stretched, and in rare cases it is grossly ruptured. Microscopically, of course, the individual fibers of the conoid and trapezoid ligaments are necessarily torn during injury. The observations made in this study further suggest that the capacity of these ligaments for healing and repair is excellent, and is sufficient to aid reconstitution of the joint relationships.

SPECIAL TESTS OF VALUE DURING TREATMENT

Although the clinical picture of fresh acromioclavicular separation is familiar to all surgeons, special tests that apply during the course of the injury deserve emphasis.

(A) *Widening of the Joint Space*

In some cases (Fig. 1-E) in which the outer end of the clavicle is characteristically above and posterior to the acromion process, it may be possible apparently to reduce the dislocation and to obliterate the deformity without difficulty, but the roentgenogram may show measurable separation or widening of the joint space (Figs. 3 and 4). In such cases, if both clavicles are outlined with the examining finger tips, it can easily be ascertained that, while the upward displacement of the dislocated clavicle is corrected, there is still slight posterior displacement. Further manipulations may correct the position in a fresh case, but are not likely to be effective in older cases.

(B) *Ballottement*

Observations in this series suggest that, although the number of cases is too small to permit definitive statements, if free floating of the distal end of the clavicle (ballottement) is observed at the end of three weeks or more of conservative treatment, this form of treatment is not likely to be effective. The phenomenon was observed in four cases in this series and was striking in Cases 4 and 5. Both were instances of posterior displacement and were treated conservatively in the splint devised by the writer, which will be described later. In each case, ballottement was evident when the shoulder strap of the splint was turned back at the end of three weeks and the distal end of the clavicle was pushed downward and anteriorly to attempt an adjustment. At the end of six weeks, when the splint was removed, the dislocation was only partially corrected, and subluxation was evident in the course of three weeks of rehabilitation. When the distal end of the clavicle was later excised, because of complaints of pain and a feeling of instability, fibrous connective tissue, capsular ligament, and torn meniscus were found interposed between the joint surfaces;

TABLE II

SIGNIFICANT DATA IN EIGHTEEN COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT TREATED BY EARLY REDUCTION AND IMMOBILIZATION FOR SIX WEEKS *

Case No.	Type of Joint	Position at Four Weeks	Ballottement at Four Weeks	Calcification in Coracoclavicular Ligaments	Cosmetic Result	Residual Symptoms
1	Overriding	Excellent	+	+	Excellent	None
2	Overriding	Excellent	+	0	Good	Pain
3	Overriding	Good	0	+	Excellent	None
4	Overriding, nearly vertical	Good	0	+	Fair	None
5	Nearly vertical	Wide joint space	+	0	Subluxation	Pain
6	Incongruent, vertical	Wide joint space	+	+	Slight subluxation	Pain
7	Overriding	Excellent	0	+	Perfect	None
8	Overriding	Excellent	0	0	Perfect	None
9	Overriding	Excellent	0	0	Excellent	None
10	Incongruent, vertical	Excellent	0	+	Excellent	None
11	Overriding	Excellent	0		Excellent	
12	Overriding	Slightly wide joint space	0	+	Excellent	None
13	Overriding	Slightly wide joint space	0	0	Excellent	None
14	Overriding	Excellent	0	0	Excellent	None
15	Overriding	Excellent	0	0	Excellent	None
16	Vertical	Good	-	+ With avulsion fracture of the clavicle	Slight subluxation	Pain
17	Vertical	Good	-	0	Slight subluxation	Slight pain
18	Nearly vertical	Good	+	0	Subluxation	Slight pain

* In Cases 16, 17, and 18 the patients were seen ten days after injury, at which time they were transferred from adhesive strappings to the author's splint. A fracture of the acromion process was associated with the dislocation in Case 4, of the coracoid process in Case 7, and of the clavicle (avulsion type) in Case 16.

they obviously prevented accurate reposition and presumably caused the free floating of the clavicle observed before operation. The same findings were also noted at operation in three other cases.

The test for ballottement of the clavicle is particularly informative after three weeks, when uncomplicated or well-reduced dislocations ordinarily become stable as the result of healing of the capsular ligament and repair of the attachments of the deltoid muscle; and a positive test, as has been stated, suggests that conservative treatment may be ineffective.

(C) *Evolution of Symptoms*

It is important that symptoms complained of in instances of recurrent or untreated subluxation be carefully evaluated. At the end of three weeks, when joint effusion and periarticular swelling and tenderness have disappeared, a complete dislocation with overriding and with no contact of the clavicle and the acromion process is not likely to be very painful. Most soldiers minimize the symptoms, which may, however, be aggravated if the men are called upon to do hard work. In a certain (unknown) proportion of such cases, residual subluxation following conservative treatment of complete dislocations is associated with pain and annoying crepitation, with or without limitation of motion of the shoulder joint. Under these circumstances, the validity of the symptoms must be studied carefully. Men in civil life are likely to disregard the deformity and to refuse surgical treatment; while

TABLE III

SIGNIFICANT DATA IN ELEVEN COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT SEEN LATE AND NOT TREATED

Case No.	Type of Joint	Primary Treatment	Days of Healing	Calcification in Coracoclavicular Ligaments	Osteo-Arthritis	Residual Symptoms
19	Overriding	Hunkin's cast	56	0	+	Subluxation
20	Vertical	Watson-Jones's adhesive splint	58	+	0	Subluxation
21	Congruent, vertical	Watson-Jones's adhesive splint	35	0	+	Subluxation
22	Overriding	Jones's humeral splint	34	+	+	Subluxation and Erb-Duchenne palsy
23	Underriding	Stimpson's adhesive splint	395	+	+	Subluxation
24	Vertical	Velpeau adhesive splint	270	+	+	Dislocation
25	Overriding	No treatment	35	+	+	Dislocation
26	Vertical	Velpeau bandage	70	+	0	Dislocation
27	Overriding	None	42	0	+	Dislocation
28	Incongruent, overriding	None	300	0	0	Subluxation
29	Incongruent, overriding	None	330	0	+	Subluxation

women will accept or ask for surgery, because they regard the protrusion of the bone on the shoulder as unsightly.)

The following objective tests are useful in confirming the validity of the patient's complaints:

1. When the patient leans against a wall, thus pressing the inferior angle of the scapula firmly and sharply on the posterior aspect of the thorax, pain in the acromioclavicular joint may be elicited.

2. When the patient elevates the arm, pain is elicited in cases complicated by synovitis, fibrous ankylosis, or arthritis of the joint. Full elevation of the arm may be impossible.

3. When the patient shrugs the shoulder, rotates the arm internally, or carries a weight, palpable crepitations or subjective grating sensations are accentuated. (The standard weight, used to amplify the deformity for a roentgenographic record, is a thirty-five-pound bucket of sand in each hand.)

4. Pain or ankylosis of the joint may prevent crossing the elbows anteriorly (adduction).

TABLE IV

SIGNIFICANT DATA IN FIVE COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT TREATED PRIMARILY BY VARIOUS METHODS

Case No.	Type of Joint	Primary Treatment	Cosmetic Result	Residual Symptoms
30	Overriding, nearly vertical	Skeletal traction	Excellent	Pain
31	Overriding	Skeletal traction	Excellent	Slight pain
32	Overriding	Phemister's trans-articular wire	Slight subluxation	None
33	Overriding	Coracoclavicular screw	Slight deformity	None
34	Overriding with fracture of acromion and coracoid processes	Thoracobrachial spica, 90 degrees abduction	Excellent	Pain and stiffness

In determining the necessity for further treatment, it is also desirable to take into consideration the character and structure of the acromioclavicular joint. In this series it was found that patients who had no symptoms after conservative treatment (Table II) often presented the overriding type of clavicle, whereas patients showing complications (Table IV) frequently presented vertical or partially undergliding joints. Subchondral compression fractures were found in two cases in this group (Cases 5 and 41). Although the number of cases is too small for positive statements, it may be possible that individuals with vertical or undergliding joints are more likely than those with other types of joint to respond poorly to conservative treatment and to develop complications.

TREATMENT

The purpose of treatment in dislocations of the acromioclavicular joint is twofold,—to secure anatomical reposition and to relieve symptoms. These objectives are interrelated; but anatomical restoration of the joint does not always relieve symptoms, which may originate in residual damage to the articular surface and the joint capsule, whereas a patient with a poor anatomical result may have no symptoms at all. Furthermore, although clinical examination and roentgenograms may show the bones in perfect position after immobilization for the proper length of time, the dislocation will recur, when the splint is removed, if healing has not reestablished the continuity of the periarticular ligaments.

Since Thorndike and Quigley's plea for conservatism in the management of dislocations of the acromioclavicular joint, it has become established that a very high percentage of incomplete dislocations or subluxations can be managed by the use of only the simplest of adhesive dressings. On the other hand, failure to obtain a satisfactory cosmetic result in some instances of subluxation, as well as the occurrence of painful sequelae and of limitation of motion, is equally well known.

An analysis of the literature, as well as the results in this series of forty-one cases of complete dislocation of the acromioclavicular joint, indicates that from 10 to 20 per cent. of the cases treated conservatively with improved methods show residual subluxations or some degree of disability as the result of pain, instability, and limitation of joint motion.

Professor E. S. Cooper of San Francisco, who was apparently the first surgeon to operate for this lesion, "ventured" to suture the acromion process to the distal end of the clavicle on a woman who "had a nervous desire to get rid of the deformity amounting almost to insanity". Although such an operation was then a very daring thing, he reported that to admit the atmosphere to bones is not a source of injury to the patient, and was "satisfied to rest the justification of its [the procedure's] claims to value upon the statistic of results in future operations".

At present, as in Cooper's time, experienced clinicians frequently find that complete dislocation of the outer end of the clavicle is difficult to manage by conservative methods[14,16,49,53], and that some degree of deformity is almost the rule[32,57,68,89] if operation is not done. The selection of the cases which require surgery after conservative treatment, correctly applied, has failed to achieve results, must be based on an evaluation of the individual patient and of his complaints. The type of operation and the time at which it should be undertaken are less open to argument. To speak categorically, surgery is necessary in untreated cases, in neglected cases, and in properly treated cases which improve so little under conservative measures within three or four weeks that it is unwise to require the patient to continue such therapy longer (Table III).

MANIPULATION AND REDUCTION

The following methods of manipulation are known to reduce most acromioclavicular dislocations, and they were used in various cases in this series to correct the deformity before the application of splints:

1. The surgeon depresses the prominent distal end of the clavicle by means of pressure by the thumb over a small felt pad[89].

2. As an alternate method, the surgeon elevates the scapula and acromion process by elevation of the flexed elbow[23].

3. The patient, while supine, is instructed (a) to throw his shoulders back[70]; (b) to abduct the arm 90 degrees or more[61]; or (c) to hyperextend the head, in order to relax the pull of the trapezius on the outer end of the clavicle[13].

4. The patient, while erect, is instructed (a) to throw the shoulders upward and backward[20,60,93]; or (b) to abduct the shoulder 90 degrees or more[49].

Combinations of Methods 1 and 2 are most widely applied to obtain the desired position for immobilization in a brachioclavicular splint. In Methods 3 and 4, the surgeon instructs the patient in the necessary manoeuvres, or may carry them out on him, as is most convenient.

The experience of all observers is that, although maintenance of the dislocated joint in position for the necessary six weeks is difficult, reduction of the dislocation is usually easy. There are, however, several obstacles to complete reduction in the occasional case, which are not revealed by casual inspection. The clavicle, for instance, may slide into position rotated on its long axis (Case 5), or may lie posterior to the acromion process even when held down at the correct level by manual pressure (Case 4). As pointed out previously, the cause of these difficulties was found, in cases later treated by excision of the distal end of the clavicle, to be due to interposition of the meniscus, frayed ends of capsular ligament, and flakes of articular cartilage.

If the acromioclavicular joint is ruptured, it is possible to overcorrect the deformity by pushing the clavicle down below the level of the acromion process. In two cases in this series (Cases 8 and 18), immobilization in this position resulted in an excellent cosmetic and functional result.

CONSERVATIVE METHODS

Following reduction of the dislocation, various types of splints and other apparatus have been used to maintain the position in which the lesion would heal, it being generally agreed that the time required for this process is six weeks.

Bandages: Slings and bandages, although very valuable for first aid, are seldom used in the definitive treatment of dislocations of the acromioclavicular joint. The brachioclavicular slings and bandages devised by Pilcher, Desault, Velpeau, Jones, and Lund are difficult for modern surgeons to apply[1], because they have had little or no practice with them, and the bandages must be painfully tight if they are to be effective for any length of time[14]. Copher revived the bandage technique[93] with his description of a figure-of-eight elastic bandage so applied as to elevate and retract the shoulders.

Adhesive Dressings and Strappings: Adhesive brachioclavicular slings have been described by Stimson, Sayre, Nichols and Smith, Gordon, and Martin. Watson-Jones's adhesive sling is a modification of the bandage devised by Sir Robert Jones. Thorndike and Quigley's method involves the application of strappings over the shoulder and across the chest to depress the clavicle, but does not elevate the scapula.

The disadvantage of all methods requiring the use of adhesive strapping is that perspiration and skin irritation make the patient extremely uncomfortable and are real obstacles to treatment for the required length of time. Improved techniques, which include the use of protective felt boards[4,89], coaptation splints[39], elastic fabrics[30], and elastoplast[5], still do not obviate the necessary removal and reapplication of the dressing, which are almost as unpleasant for the physician as for the patient.

Suspension: Barr, Metz, and Caldwell[14] suspended the arm in a Balkan frame in 90 degrees or more of abduction on the affected side, and this is a valuable method for bedridden patients who must be treated for other injuries or complications. All the evidence

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Shows separate application of padded arm and body plasters.
Fig. 1-B: The elastic shoulder strap is made of a strip of salvaged inner tube. The rubber is stretched tightly over the clavicle, with its ends doubled back on themselves between layers of plaster bandage, to maintain constant pressure. The next step (completed in Fig. 1-C) elevates the scapula, as in the method of Dillehunt (inset)[23,61].

FIG. 1-C

FIG. 1-D

Fig. 1-C: Arm section of plaster has been fixed to body section and elevated to a position which holds the shoulder on the affected side one or two inches higher than the shoulder on the intact side.
Fig. 1-D: Continuous pressure is maintained by wide area of thickly padded shoulder strap. Immobilization can be effected comfortably and without interruption for six weeks by this method. Support of body plaster on iliac crests gives countertraction and aids in maintaining elevation of arm on body.

in the literature, however, is to the effect that these methods, which have the advantage of simplicity and the disadvantage of inconvenience, have not proved to be sufficient to effect repair in cases of complete dislocation of the acromioclavicular joint.

Harnesses and Braces: Currie, Warner, Rawlings, and Giannestras devised harnesses which follow the pattern of the brachioclavicular sling. Shaar and Howard described harnesses equipped with elastics to compress the acromial end of the clavicle. Roger Anderson's abduction brace differs from all others in that it elevates the shoulder by means of a padded cradle under the axilla, and depresses the clavicle by means of an attached shoulder strap.

FIG. 1-E

FIG. 1-F

Fig. 1-E: Roentgenogram showing the dislocated clavicle before treatment. This is the overriding type of joint.

Fig. 1-F: Roentgenogram of dislocated left shoulder immediately after reduction to anatomical position in author's splint. Note slight overcorrection of dislocation, as shown by comparison of distances between coracoid process and clavicle in the reduced left joint and the intact right joint (Fig. 1-E).

The efficiency of all of these appliances is proportional to the amount of supervision and instruction given the patient. The efficiency of the Roger Anderson brace is obviously good, and in the tropics[75] such forms of treatment are desirable because they afford greater comfort for the patient. On the other hand, the cost and availability of fitted apparatus of any kind always limits its use.

Plaster-of-Paris Splints: Innumerable splints have been devised for the correction of acromioclavicular dislocation by plaster techniques, all of which have both advantages and disadvantages. Hunkin's splint[101] is a loose plaster torso cast, suspended from a webbed shoulder strap. Gibbens's is a hanging arm cast, suspended from an elastic band over the shoulder, the principle being that the weight of the plaster will depress the outer end of the clavicle. In both this method and that of Hunkin, the effort to maintain reduction is relaxed whenever the patient lies down.

Key and Conwell recommended a thoracobrachial spica with 90 degrees of abduction, and Hart recommended a cast with 45 degrees of abduction; in the latter method a webbed shoulder strap maintains position, partly by abduction and partly by pressure. The surgeons who advise abduction do not state its effect on the anteroposterior position of the clavicle when the joint capsule is ruptured, but there is probably some posterior displacement which must be corrected by pressure on the outer end of the clavicle. When the dislocation is complicated by a fracture of the acromion process, the joint surfaces, or the coracoid process, the shoulder spica[49], as well as the brachioclavicular cast devised by Böhler, is essentially a compromise to secure comfortable immobilization for the patient (Case 5). Trynin and Legg also devised plaster brachioclavicular casts, Legg's being a Velpeau bandage (reported by Girard), the efficiency of which is increased by the addition of an adjustable elastic shoulder strap. The pressure of the shoulder strap in brachioclavicular slings, without elevation of the scapula, especially in techniques which utilize gravity, is usually too much to be tolerated by the skin for six weeks, although moderate compression of the outer end of the clavicle, preferably by an elastic strap, is necessary to produce perfect anatomical realignment.

Dillehunt's torso cast elevates the acromion process, until it is aligned with the distal end of the clavicle, by fixing and elevating the arm on the side of the chest (Fig. 1-B). This counteracts the pull of the trapezius and at the same time cancels the weight of the arm, thus achieving reduction and immobilization with very little force.

The splint devised by the writer for the correction of complete dislocation of the acromioclavicular joint incorporates the most desirable features of the splints devised by

FIG. 2

Case 8. Roentgenogram of left acromioclavicular dislocation, sustained in a motorcycle accident, after reduction and overcorrection in author's splint. Arrows indicate points of main pressure of shoulder strap on clavicle, which do not show clearly in film.

Dillehunt, Shaar, Howard, and Legg. In particular, as in Dillehunt's splint, elevation of the scapula is maintained by anchoring the body plaster to the iliac crests, to provide the necessary counterbalance. The defect in all of these splints is that they fail to depress the clavicle below the level of the acromion process. This feature is desirable, because it overcorrects the deformity. It is necessary to the best cosmetic and functional end result and is provided in the author's modification (Figs. 1-F and 2) by the elastic shoulder strap, which supplies the necessary clavicular depression without excessive cutaneous pressure.

The modified splint should be applied early, before organization of the hematoma and healing in the tissues around the lesion is under way. It must be realized that the splint has the disadvantage of restricting movement of the arm or of the chest, which some surgeons prefer to avoid[1,35,99].

END RESULTS OF CONSERVATIVE TREATMENT

Fifteen soldiers with complete dislocations of the acromioclavicular joint, who had been evacuated promptly from forward areas in first-aid bandages or temporary adhesive strappings, were treated by application of the writer's splint (Figs. 1-A to 1-E, inclusive, and Fig. 2) for the required six weeks. In no instance was any untoward effect on the elbow observed when the splint was removed. Twelve patients returned to duty as completely cured after a period of physical therapy and rehabilitation. Another patient, in whom subluxation developed without pain or limitation of motion, also returned to unrestricted military duty, which did not increase the deformity. The two remaining patients (Cases 5 and 6) presented subluxations associated with symptoms after several days of physical therapy, following the removal of the casts, and eventually were subjected to surgical treatment.

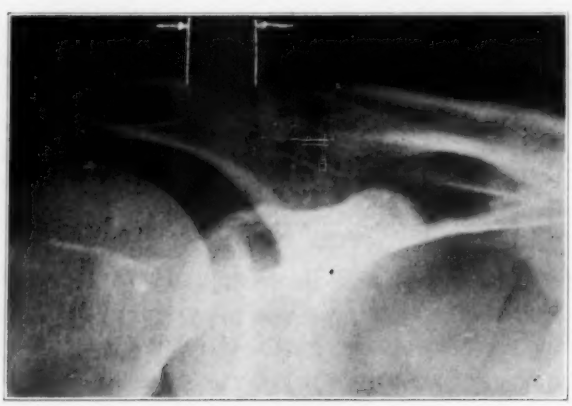

FIG. 3

Case 17. Roentgenogram of severe dislocation of right acromioclavicular joint, sustained in a motorcycle accident. Interposition of the capsular ligament is suspected, because the joint space was greatly increased on the affected side after reduction of the dislocation. This is the vertical type of joint.

These fifteen patients, who were seen early enough to be treated by conservative methods, wore the splint for six weeks and had two weeks of physical therapy before the first record of results was made. All, however, were examined from three to four weeks after the application of the splint by folding the shoulder strap medially on itself and determining the mobility of the acromial end of the clavicle. Three patients (Cases 5, 6, and 34) showed free floating of the outer end of the clavicle (ballottement), as well as pain, swelling, and tenderness over the joint. In all of these cases the deformity recurred at six weeks, when the splint was removed. Operations in Cases 5 and 6 revealed interposition of the capsular

FIG. 4

Case 16. Roentgenogram of severe dislocation of right acromioclavicular joint, sustained in fall over fence on dark battlefield. Correction has been obtained by author's splint. A false impression of overcorrection of the deformity may be obtained when, as in this case, the clavicle is displaced posterior to the acromion, but is actually farther from the coracoid process than on the opposite side. If treatment is undertaken early, the faulty position can be improved by manipulation under the shoulder strap.

ligaments and interference with satisfactory reduction of the dislocations, which were not evident in anteroposterior roentgenograms of the shoulder. If a larger experience confirms these early observations, the sign of the free floating end of the clavicle may indicate the cases in which conservative treatment should be abandoned early.

The results in these fifteen cases are in accord with those of other observers[47,51,93], whose reports show 10 to 20 per cent. of failures by newer conservative methods of treatment. Many surgeons are convinced that complete dislocations respond to non-operative methods of treatment in a high percentage of cases[1,26,92,99], while others, equally experienced, are rather pessimistic[19,32,45,62,83,85,97]. The periodic revival of the concept that strappings are adequate for all cases, if rigorously tended, is generally disregarded by surgeons who have observed the comforts of more effective, newer methods[1,23,37,47,82]. It should also be emphasized that many papers which present highly successful results with obviously inadequate methods of treatment deal only with sprains, subluxations, or incomplete dislocations of minor degree, such as the average football injury sustained in "blocking", and not with complete dislocations[26,47].

Three other patients (Cases 16, 17, and 18) were seen ten days after injury, in adhesive strappings, from which they were transferred to the writer's splints for six weeks of additional immobilization. At the end of treatment, varying degrees of subluxation were present in all cases, but the associated symptoms were neither severe nor disabling. All three patients returned to duty, apparently perfectly satisfied with the results obtained.

The following case report illustrates the successful result of conservative therapy:

CASE 1. This patient, while sitting in the front seat of a jeep, was thrown out after a head-on collision with another vehicle and struck his right shoulder on the pavement. The application of a Velpeau bandage in a local dispensary failed to hold the shoulder in a satisfactory position. Twenty-four hours later the dislocation was reduced and the shoulder was immobilized in the writer's splint (Figs. 1-A to 1-D), which was maintained unchanged for six weeks. At the end of this period, roentgenographic examination showed the correct anatomical position. There was slight induration about the acromioclavicular joint and slight crepitus was observed, but the patient had full range of motion and no symptoms were present after ten days of physical therapy. He returned to full duty, including calisthenics and sports, eight weeks after the injury.

SURGICAL METHODS

Among the various surgical methods for the treatment of complete dislocation of the acromioclavicular joint, the most important are arthrotomy and internal fixation, arthrodesis, coracoclavicular screw fixation, syndesmoplasty, ligamentopexy, and arthroplasty. One patient in this series was treated by open reduction and internal fixation with a transarticular wire (Case 32), one by the coracoclavicular screw (Case 33), two by skeletal traction (Cases 30 and 31), and nine by excision of the outer end of the clavicle (Table V).

TABLE V

SIGNIFICANT DATA IN NINE COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT TREATED BY EXCISION OF THE DISTAL END OF THE CLAVICLE

Case No.	Type of Joint	Primary Treatment	Result	Interval Before Surgery	Operative Findings	
					Coracoclavicular Ligaments	Joint
35	Overriding	Stimson's strapping	Poor	4 weeks	Stretched, but intact	Fibrous adhesions
36	Overriding	Watson-Jones's strapping	Poor	4 weeks	Trapezoid stretched and frayed	Interposed capsule and fibrous adhesions
37	Overriding	None	Poor	3 weeks	Intact	Interposed capsule and fibrous adhesions
38	Incongruent, overriding	None	Dislocation	12 months	Intact	Chronic synovitis or fibrous ankylosis
39	Incongruent, overriding	Adhesive brachioclavicular sling	Subluxation	11 months	Ossified	Extra-articular new bone
40	Incongruent, overriding	Arm sling	Subluxation	10 months	Ossified	Extra-articular new bone
41	Incongruent, overriding	Velpeau bandage	Subluxation	5 months	Intact	Interposed fibrous connective tissue
5*	Vertical	Author's splint	Subluxation	10 weeks	Intact	Interposed capsule and fibrous adhesions
6*	Incongruent, vertical	Author's splint	Subluxation	10 weeks	Intact	Interposed capsule and fibrous adhesions

* See Table II for additional details concerning these two cases.

Arthrotomy and Internal Fixation

Many surgeons[64,78,97] have reported good results, including correction of the deformity, following arthrotomy and internal fixation by silver wire[19,97], phosphobronze wire[58], steel wire[16,29,50], chromic catgut[33,76], screws[13], Parham bands, silk[43,63], and fascia[31], among other materials. Improvement in results has been reported by the use of extra-articular suture with arthrotomy in combination with arthroplasty, or by the use of periarticular[91] or coracoclavicular screws without arthrotomy[10,99].

Bloom and Phemister have reported good results following the use of transarticular Kirschner wires with arthrotomy, and Murray has used the same method without arthrotomy. The three authors report a total of twenty-seven cases. An extra-articular technique with Kirschner wire is also mentioned[84]. The writer observed one case (Case 32) six months after the operation, treated by another surgeon, in which the deformity was corrected satisfactorily by Phemister's technique.

The end results in all these operations depend, just as when non-surgical methods are used, on the healing of the ligaments and of the periarticular structures. These surgical measures should be instituted early; they are more likely to be unsuccessful in neglected or old dislocations. The theoretical advantage of arthrotomy is that more accurate fixation of the non-osseous parts of the joint can be achieved by reposition and suture under direct vision, but the reports suggest that the cosmetic results and symptomatic cures are approximately the same as those achieved by the writer and by others[47,93] who used improved conservative methods.

Arthrodesis

Before World War I, operations for suturing the acromioclavicular joint frequently resulted in ankylosis. Later, the articular cartilages were resected, to ensure bony fusion, which would correct deformity and relieve pain. Limitation of motion of the shoulder,

FIG. 5-A

FIG. 5-B

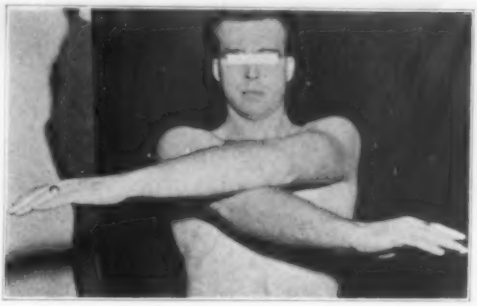

FIG. 5-D

FIG. 5-C

Fig. 5-A: Case 5. Complete dislocation of left acromioclavicular joint was sustained in a football game. Photograph taken ten days after excision of outer end of clavicle and just after removal of sutures from the incision, through which the coracoclavicular ligaments were also explored. The affected shoulder is slightly lower than the intact shoulder as the scapula falls forward and lower on the thorax.

Fig. 5-B: Twenty-one days after operation, full elevation of arm is possible.

Fig. 5-C: Functional result fifteen days after operation; range of active abduction is 90 degrees.

Fig. 5-D: Functional result twenty-eight days after operation; painless crossing of elbows on the chest is seldom possible with any appreciable acromioclavicular separation.

particularly of abduction, was soon observed in such cases; and experimental observations on cadavera furnished the explanation, which is that the articulations of the clavicle, the scapula, and the humerus must function independently for elevation of the arm. Arthrodesis of the acromioclavicular joint is mentioned repeatedly in the literature up to the present time[14] as a solution for the problem of complete dislocation. It is not, however, an acceptable procedure. As Inman and his associates have pointed out, the clavicle rotates on its long axis and must not be fixed, if comfortable elevation of the arm beyond 90 degrees is expected to continue.

Coracoclavicular Screw Fixation

Bosworth in 1941 used a lag screw, inserted through the clavicle into the coracoid process, to fix the position of the dislocation; he employed the method in four cases. Experienced clinicians[94,99], who currently advocate the method, teach that the screw must not be turned so tightly as to prevent "normal" motion of the clavicle, and they also advocate active exercises after operation.

The writer's experience is that normal motion of the clavicle is impossible with this method of fixation, since the clavicle rotates on its long axis with abduction. The effect on the shoulder as a whole is the same as the effect of fusion of the acromioclavicular joint[13,64]; the fixation of the clavicle to the scapula limits abduction of the arm and causes pain, if motion is attempted beyond 90 degrees[48].

Watson-Jones, who recommends removal of the screw after four to six weeks in most cases, reports that results by this method are better than after conservative methods, by

FIG. 6

FIG. 7

Fig. 6: Case 7. Roentgenogram of avulsion fracture of medial aspect of right coracoid process, sustained in jeep accident. After overcorrection of deformity in author's splint for six weeks, this patient had a perfect cosmetic and functional result.

Fig. 7: Case 9. Roentgenogram of dislocation of right acromioclavicular process with minute fracture of distal end of inferior margin of clavicle, seven weeks after injury was sustained by tank striking tree in combat. Note calcification of inferior capsular ligament. This patient complained of pain and had limitation of abduction of the arm beyond 90 degrees. The (intact) joint is partly underriding at the inferior margin, because the articular clavicular surface is concave and the acromial surface is convex.

FIG. 8

FIG. 9

Fig 8: Case 19. Roentgenogram of dislocation of left acromioclavicular joint, seven weeks after fall from motorcycle. Note calcification under clavicle. Deposits had been evident three and one-half weeks after the accident, but did not show up clearly enough for reproduction.

Fig. 9: Case 4. Dislocation of right acromioclavicular joint, eight weeks after injury had been sustained in a motorcycle accident. Ossification of the coracoclavicular ligaments and calcification of the meniscus, with a chip fracture of the acromion, are demonstrated by soft-tissue roentgenographic technique. The joint line is nearly vertical.

which he presumably means adhesive strappings. The end results of enough documented cases are, however, not yet available to permit final statements. The writer observed one instance (Case 33) in which the screw became loose four weeks after insertion, due to bone resorption, and the application of another splint was necessary.

Treatment by the coracoclavicular screw is limited to fresh injuries, and it is doubtful whether patients who do not respond to non-surgical methods, because of the interposition of soft parts, will be aided by it. The same objections apply to it as apply to all operative methods which do not include arthrotomy.

Syndesmoplasty

Direct surgical repair of the conoid and trapezoid ligaments is probably impossible because of their inaccessibility after even the best exposure[77]; but suture has been accomplished by indirect methods, including repair of the acromioclavicular joint. Approximation of the ligaments was obtained when the clavicle was bound to the coracoid process with heavy silk[11,17,18,24,59,89] or with wire[13,19]. The periarticular ligaments have also been repaired by transfer of fascia or ligaments at the site of the lesion[13,17,95]. Conclusive information as to the final results of syndesmoplasty has not yet been recorded.

Ligamentopexy

Reconstruction of the conoid and trapezoid ligaments[11,42,45,62,85] or of the coracoclavicular and acromioclavicular ligaments[2,12,27,33,78,81] with an isograft of fascia lata is a surgical feat which, until recently, was considered an effective solution for old dislocations with extreme deformities. Henry protected the new ligament by fastening the clavicle in position with an extra-articular loop of silver wire. Bunnell's method is more difficult[11] than Henry's, but is more effective because the capsule of the acromioclavicular joint is also reinforced with fascia.

Equally experienced surgeons both recommend[9,60,66,86] and oppose[57,99] such operations. The grafts of fascia lata which form the new ligaments are reported to stretch, with subsequent recurrence of the deformity, and the disability is aggravated by postoperative stiffness of the shoulder. The fascia or old ligaments almost invariably calcify, and the resulting synosteosis limits abduction[6,54].

Skeletal Traction

Skeletal traction has been used for bedfast patients, suffering from severe injuries of the ribs and chest and other complications. It is capable of providing and maintaining the

FIG. 10

FIG. 11

Fig. 10: Case 27. Dislocation of left acromioclavicular joint, sustained in fall from moving tank. Roentgenogram shows calcification of capsular ligament four months later. The patient had mild symptoms of traumatic arthritis at this time. This is an extreme example of the overriding type of joint, the articular surfaces being nearly horizontal.

Fig. 11: Case 26. Dislocation of right acromioclavicular joint, showing coracoclavicular synosteosis, ten weeks after automobile accident caused by artillery blast. The patient had slight pain and limitation of abduction at this time. Because of other injuries, he was evacuated to the Zone of the Interior for treatment.

FIG. 12

FIG. 13

Fig. 12: Case 24. Roentgenogram of dislocation of left acromioclavicular joint, incurred when jeep rolled down an embankment under enemy fire, shows coracoclavicular synosteosis nine months later. The patient had moderate pain and was unable to abduct the arm beyond 80 degrees. (Illustration has been reversed.)

Fig. 13: Case 39. Healed dislocation of acromioclavicular joint, sustained when patient was kicked squarely on point of shoulder in a football game. Roentgenogram, ten months after accident, shows loose osteocartilaginous bodies in joint and ossification of insertions of trapezoid ligament. The patient experienced annoying crepitations, had pain when doing heavy work, and had 30 degrees of limitation of abduction.

FIG. 14-A

FIG. 14-B

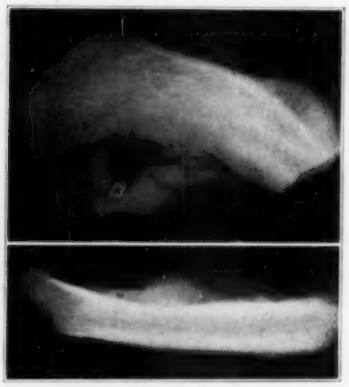

FIG. 14-C

Fig. 14-A: Case 40. Old dislocation of left acromioclavicular joint with linear fracture at junction of middle and outer thirds of clavicle, produced by direct blow over shoulder in jeep accident in combat. Note synosteosis at site of fracture, ten months after accident. Immediately after the injury, ecchymosis and marked swelling were present over the lateral aspect of the neck and the dorsum of the shoulder.

Fig. 14-B: Roentgenogram after excision of outer third of clavicle. The patient had complete relief of symptoms and returned to full duty in twelve weeks.

Fig. 14-C: Superior and inferior aspects of excised clavicle. Note new-bone formation on antero-inferior attachments of trapezoid ligament.

anatomical position continuously for four weeks, as shown in anteroposterior and oblique roentgenograms. Traction is obtained by the use of small threaded pins,—two inserted in the outer third of the clavicle and one inserted into the coracoid process and tied together in a triangle with elastics. Rubber bands serve, in effect, as a second, external set of ligaments, and maintain reduction by continuous skeletal traction. The patient, to relieve the tension, involuntarily elevates the shoulder on the affected side and thus actively aids in maintaining the reduction.

The method can be used only on fresh cases. All the well-known disadvantages of external skeletal fixation obtain, and the use of the technique should be limited to unusual circumstances. This is not a method applicable to military or industrial practice.

Excision of the Outer End of the Clavicle

Morestin, late in the Nineteenth Century, resected just enough of the outer end of the clavicle in two cases of acromioclavicular separation to remove the subcutaneous projection of the bone, and similar operations have been done for osteomyelitis and for tumors[28]. Surgical excision of the outer end of the clavicle has frequently been done for arthritis and other conditions[67,99]. These operations, as well as parallel observations on individuals with partial[88] or complete absence of the clavicle[72], led to the conclusion that absence of the clavicle is better than acromioclavicular ankylosis, and that there is little postoperative disability, other than possibly slight impairment of the muscle coordination needed for forceful forward thrusts of the arm or for acrobatics[46].

Mumford and Gurd almost simultaneously revived interest in this operation, both for fresh cases and for old dislocations of the acromioclavicular joint. Rowe added suture of the cut end of the clavicle to the coracoid process with nylon, but most surgeons do not regard this as a necessary part of the operation. The writer resects from six to eight centimeters of the clavicle, so that the stump is excluded from interference with the motions of the scapulohumeral joint.

This method attained wide favor in the Armed Forces, and nine cases in this series were so treated (Table V) after conservative methods had failed. The cosmetic result in all instances was excellent (Figs. 5-B and 5-D), as the contour of the dorsum of the shoulder was maintained by the acromion; but neither the function nor the appearance of the shoulder should be described as "normal". A patient in whom the outer end of the clavicle has been excised clearly demonstrates that the clavicle acts as a kind of yardarm, which prevents the shoulder from falling anteriorly and inferiorly on the chest wall (Fig. 5-A), and that this is probably its most important function in man. In young men, the musculature of the shoulder girdle compensates for the stability which is lost with the absence of the clavicle, but all of the nine patients admit having earlier fatigue or slight weakness in the shoulder on prolonged vigorous exercise, as compared with the intact opposite side. Disability and pain from the acromioclavicular dislocation, however, were relieved completely within a few weeks after the operation.

The two case histories which follow illustrate the indications and results of this surgical method.

CASE 5. A football player was struck sharply over the dorsum of the shoulder by an opponent, who blocked him out of a line play. A Velpeau bandage was applied at an aid station, and was replaced two days later by the splint devised by the writer. Roentgenograms showed excellent reduction, but with slight widening of the acromioclavicular joint as compared with the joint on the opposite, intact side. Four weeks after the injury, the distal end of the clavicle was abnormally mobile and apparently floating free. At six weeks, the splint was removed and daily exercises at the shoulder wheel were begun. At eight weeks there was 30 degrees of limitation of elevation of the arm, and pain and crepitus were experienced when the patient was at the shoulder wheel. The distal end of the clavicle rose out of the joint when the arms were folded across the chest. Ten weeks after the injury, the soldier was examined in the outpatient clinic and it was concluded that his complaints were justified and that further treatment was indicated. The distal end of the clavicle was therefore excised. Exercises were begun before the sutures were removed. Three weeks after operation there was no deformity, no limitation of motion, no crepitus, and no other symptoms or disability. The patient cheerfully returned to full duty. This case represents one of the instances in which the ruptured acromioclavicular joint fails to heal under ideal conditions.

CASE 40. This patient sustained a fracture of the left clavicle, with separation of the acromioclavicular joint, in a jeep accident in France. The fracture healed uneventfully and in good position, and the soldier returned to combat. Nine and one-half months after the accident, he reported that pain had begun in the left shoulder and had become increasingly severe. It was aggravated by exercise in games and calisthenics. Physical examination showed that the clavicle on the injured side was more prominent than on the normal side; the acromioclavicular joint was painful to palpation, but was not abnormally mobile. There was 30 degrees of limitation of abduction of the arm. Roentgenograms showed a well-healed fracture at the junction of the middle and outer thirds of the clavicle, with synosteosis between the fracture site and the coracoid process and ossification of the conoid and trapezoid ligaments.

At operation, a mass of bone and scar tissue was found throughout the insertion of the subclavius muscle and the region of the coracoclavicular ligaments. A column of bone was palpable between the site of the old fracture and the coracoid process. The distal third of the clavicle and the ossified coracoclavicular ligaments and scar were removed *en masse*, with a minimum of dissection. Physical therapy was begun as soon as the sutures had been removed. At the end of three weeks the patient could lift heavy weights and had full range of motion; he was therefore discharged to full duty.

ASSOCIATED FRACTURES

As already noted, eleven patients in this series presented, in addition to complete dislocation of the acromioclavicular joint, twelve associated fractures, distributed as follows:

Clavicle (Eight Fractures): One was a transverse fracture at the junction of the middle and outer thirds of the shaft (Case 40); four were subchondral compression fractures (Cases 5, 35, 36, and 41); one was a chip fracture of the acromial end of the inferior margin, in a partially undergliding joint (Case 9, Fig. 7); and two were avulsion fractures of the trapezoid ridge (Cases 8 and 16).

Acromion Process (Two Fractures): One was a chip fracture (Case 4, Fig. 9) and one a fissure fracture (Case 34).

Coracoid Process (*Two Avulsion Fractures,* Cases 7 and 34): The fracture in Case 34 was in addition to a subchondral compression fracture of the clavicle.

As is true of similar traumatic lesions in dislocations in other areas of the body, the ligament presumably suffered less damage when its bony insertion was avulsed. The presence of avulsion fractures of the coracoid process did not influence healing adversely, and conservative therapy gave good results in both cases; ossification of the coracoclavicular ligaments occurred in all. The same was true of the single avulsion fracture of the inferior surface of the clavicle. Painful abduction was present in three of the five cases in which articular surfaces were involved in the injury, and painful joints persisted for a time in all but these symptoms eventually disappeared in all but one case (Case 8), in which excision of the outer third of the clavicle was eventually necessary.

Primary excision of the joint is probably not justified in dislocations associated with fractures in military surgery, until a period of duty establishes disability, as the following case shows.

CASE 34. This patient, an engineer, was struck on the left shoulder by a falling beam as he was working with a crane. Roentgenographic examination, one hour later, showed a linear fracture of the acromion process without displacement, avulsion of the coracoid process, and acromioclavicular separation.

Because of the swelling and ecchymosis over the dorsum of the shoulder, the plaster-of-Paris abduction splint of Key and Conwell was considered more practical than the Legg-Girard splint, which requires the pressure of a shoulder strap. (The acromioclavicular separation, however, is only partially reduced by this method, because the distal end of the clavicle is displaced slightly posteriorly, and the distance between the clavicle and the acromion process is undesirably increased.)

At the end of two weeks, the dorsal section of the cast was removed, and massage and biceps-setting exercises were ordered. At six weeks, the remainder of the cast was removed and limited exercises were undertaken. At eight weeks, the patient began to use the shoulder wheel. Roentgenographic examination at this time showed union of the coracoid process to the scapula and complete healing of the fracture of the acromion process. When the patient returned to duty, twelve weeks after the accident, he had a slight subluxation, but was free from symptoms.

COMPLICATIONS AND SEQUELAE

Pain and limitation of motion may develop early or late and in any type of case, regardless of whether it was untreated, poorly treated, or well treated. The management depends upon the etiology.

Arthritis

Osteo-arthritic changes in the articular surfaces of the acromioclavicular joint, calcifications in the capsular ligament, and loose osteocartilaginous bodies were found on roentgenographic examination in twelve cases in this series (Figs. 9, 10, and 13). Five were treated by excision of the distal end of the clavicle, and had complete relief of symptoms within three weeks after operation.

Atrophy or rarefaction of the acromial end of the clavicle was apparent in the roentgenograms in almost all severe or old cases. When immobilization was discontinued, if the dislocation remained reduced and normal function had been resumed, the density of the bone gradually returned to normal.

In two cases in this series (Cases 35 and 36), so-called avascular necrosis or osteochondritis[89] was observed. In both cases, subchondral fractures were found at open operation. Gross examination and roentgenographic examination of the excised specimens showed sclerosis of old bone, irregular areas of resorption, and new subperiosteal bone formation, typical of the process of healing of crushed spongiosa. Avascular necrosis is not frequent, but should be expected in severe cases, as demonstrated by the roentgenograms, whether or not reduction has been accomplished.

All the changes described, although they are regarded as evidence of traumatic arthritis by many observers[13,55,60,67,99], do not necessarily give rise to symptoms. Although they were present in roentgenographic examinations in twelve cases, only seven of the patients had genuine pain.

Calcification and Ossification of Soft Parts

Calcified structures between the coracoid process and the clavicle have frequently been described and various interpretations have been placed upon them, depending upon their location. They have appeared in ossifying hematoma[49], in a bursa between the conoid and trapezoid ligaments[56], under the torn periosteum[99], and in the substance of the torn ligaments[6,26,38,54,84,97]. Šváb demonstrated that the new bone may arise in endochondral ossification, presumably of primitive connective-tissue cells in the substance of the ligament. Wakeley regards the phenomenon as a hopeful sign of the reuniting of the torn ligaments. Ligamentopexy invariably results in ossification of the ligaments, and transplanted fascia lata in this region has the same fate[60].

Calcification of the conoid and trapezoid ligaments was demonstrated roentgenographically in eighteen of the cases in this series (Figs. 8 to 14-C). The deposits first appeared within three or four weeks after the injury, and increased in density and extent through several months of healing. The final size of the deposit varied between a fleck, which could be demonstrated only by oblique roentgenograms, by soft-tissue technique, and massive ossification of the coracoclavicular ligaments and synosteosis of the clavicle and scapula. Gross and roentgenographic examination of the new bone in excised specimens showed that it appeared in some cases as an outgrowth from the periosteum of the clavicle or the coracoid process, and in some it appeared as an unattached body.

The complaints and physical examinations in these cases showed that, up to the point of actual fusion of the clavicle and scapula, the deposits were of no clinical significance. When the synosteosis was nearly complete (Case 24), the range of motion of the coracoclavicular syndesmosis was diminished, and the effect on function was the same as if ankylosis of the acromioclavicular joint had occurred. In the case mentioned, abduction beyond 90 degrees was painful and limited, although the degree of subluxation was only moderate. Both the symptoms and the deformity were relieved by excision of the outer end of the clavicle.

Synovitis and Joint Adhesions

When synovitis and adhesions are present in acromioclavicular dislocation, the patients complain of vague pains and uncomfortable crepitations in the absence of roentgenographic changes in the bone or joint, sometimes associated with swelling over the acromioclavicular articulation. This occurs whether or not treatment of the deformity has been successful. The patients also complain of instability with extreme motions of the shoulder, although this usually disappears over a period of years. Köstler emphasizes the dislocation of the meniscus as a factor in such cases.

One patient in this series (Case 6) requested further treatment a year after treatment of a complete dislocation, on the ground that, because of the symptoms mentioned, he could not perform his duties as a stevedore. Excision of the outer end of the clavicle showed the joint cavity to be obliterated by intra-articular fibrous connective tissue, calcified capsular ligament, and torn meniscus, which Köstler has emphasized as the inciting factor in such cases.

SUMMARY AND CONCLUSIONS

1. Complete dislocation of the acromioclavicular joint may occur with, or more often without, gross rupture of the coracoclavicular ligaments. The normal excursion of the conoid and trapezoid ligaments permits dislocation when the joint alone is involved.

2. Calcification and ossification, observed with the aid of soft-tissue roentgenographic techniques, were found in the region of the conoid and trapezoid ligaments in approximately half of this series of forty-one cases. This phenomenon may be interpreted as a part of the process of healing of the ligaments.

3. The possible anatomical variations from the supposed normal joint structure may determine the success or failure of conservative treatment and the incidence of sequelae.

4. Improved methods of conservative treatment may be expected to correct the deformity and relieve symptoms in approximately 80 per cent. of the cases of complete dislocation of the acromioclavicular joint. In the remaining 20 per cent., deformity, pain, or limitation of motion may indicate the need for additional treatment by surgical measures.

5. A modification of the splints devised by Dillehunt, Howard, Shaar, and Legg is capable of overcorrection of the deformity, which is the key to success with conservative measures.

6. The chief obstacle to effective conservative treatment is interposition of soft parts,—such as meniscus, frayed capsular ligament, and flakes of articular cartilage between the joint surfaces.

7. Excision of the outer end of the clavicle, used successfully in nine cases in this series, is apparently the most uniformly successful method of treatment for both recent and old *complicated* acromioclavicular dislocations.

8. Two observations of possible diagnostic and prognostic importance were noted in the course of the study, although the limited number of cases does not permit positive statements concerning them at this time: (a) An increase in the width of the joint space on the injured side, demonstrated roentgenographically, indicates posterior displacement of the outer end of the clavicle, even when the acromion process and the clavicle are correctly aligned. (b) Palpable posterior displacement and abnormal mobility of the outer end of the clavicle, after three weeks of healing, indicate the probable failure of conservative methods and the recurrence of the dislocation.

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OBSTETRICAL DISLOCATION OF THE HIP ASSOCIATED WITH FRACTURE OF THE FEMUR

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Traumatic dislocation of the femur is rare, because the ligaments which reinforce the capsule are very strong. In cases of excessive trauma—as from energetic traction—epiphysiolysis or fracture of the femoral diaphysis may be produced, but not dislocation. It is for this reason that treatises on fractures rarely mention dislocation of the femur of obstetrical origin.

The two cases presented here are cases of real fracture-dislocation of the hip, caused by forcible manoeuvres during birth. Breech deliveries were performed in each case; the thigh was subjected to strong traction with rotation and extreme abduction during the course of the delivery.

This type of fracture-dislocation may be differentiated from the more usual type of congenital dislocation upon the basis of roentgenographic findings.

The clinical picture of the obstetrical fracture-dislocation is characteristic: After a difficult delivery, an apparent disproportion in the length of the infant's limbs will be noted. In addition, there is intense pain upon motion of the injured limb. After two or three days a swelling of the inguinal region, the thigh, and the gluteal region may be noted. There is a brawny induration, and a slight elevation of temperature of the skin. The limb is held in a characteristic position of external rotation and slight flexion.

Because of the pain, the child does not gain weight or sleep calmly. He is startled easily and has a poor appetite. He cries violently when the mother attempts to change his clothes. There is shortening of the thigh, and the greater trochanter lies above the Nélaton-Roser line.

The prognosis is favorable when treatment is undertaken within the first fifteen days after birth. In the cases presented here, the patients have been completely cured. No case of luxation with untreated fracture has been observed. The treatment consists of reduction and proper immobilization. In the reduction, the Lorenz procedure, employed in the treatment of congenital dislocation, is utilized. Under ether anaesthesia, the opposite hip

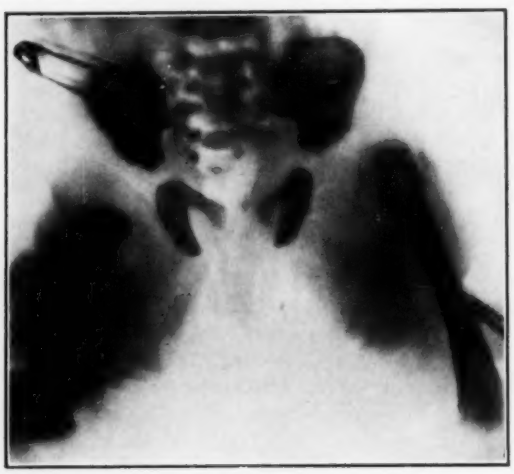

FIG. 1-A

FIG. 1-B

Fig. 1-A: Roentgenogram taken two days after birth, on October 18, 1943.
Fig. 1-B: December 29, 1943.

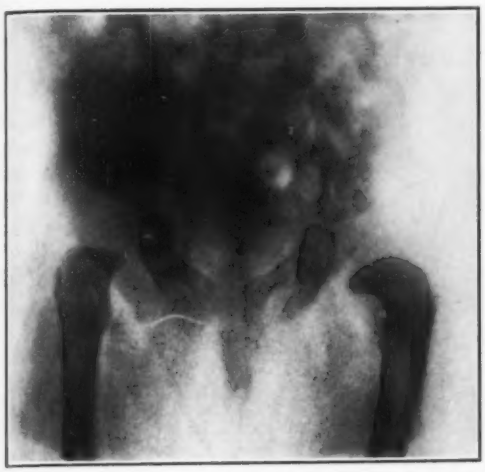

FIG. 1-C
Four months after reduction.

FIG. 1-D
April 11, 1944.

FIG. 1-E
April 11, 1944.

FIG. 1-F
July 18, 1944.

is fixed, while the operator flexes the injured thigh upon the abdomen. With both hip and knee flexed, the extremity is externally rotated. Usually a snap, produced by the head dropping into the acetabulum, is felt during the course of this manoeuvre. The reduction is performed with roentgenographic control. If satisfactory, the limb is placed in a position of 135 degrees of flexion, 40 degrees of abduction, and slight internal rotation.

FIG. 1-G
Final result, on January 9, 1946.

Castex is preferred to the ordinary plaster-of-Paris spica, because it is lighter and waterproof. The plaster is left in place for a period of forty-five days. After removal of the plaster, all other forms of treatment—such as massage and exercise—are found to be unnecessary. The results of such treatment are good, and are illustrated in the following cases.

FIG. 2-B

FIG. 2-A

Fig. 2-A: Roentgenogram taken on August 25, 1944, fifteen days after birth, before treatment was initiated.
Fig. 2-B: Final result on January 3, 1946, seventeen months after reduction.

CASE REPORTS

CASE 1. S. C., a girl, was born on October 16, 1943, after a difficult delivery, during which traction was exerted upon the left lower extremity. On the day after delivery, the parents noted a swelling of the thigh, with a slight shortening of the left limb. All movements were extremely painful, and several times the child awoke and cried out. Two days after birth, roentgenograms (Fig. 1-A) revealed a supra-acetabular subluxation. This was associated with several loose bone flakes in the cortex of the greater trochanter. There was slight elevation of the pelvis on the affected side, but the acetabulum had the same appearance as that on the normal side.

On November 3, 1943, reduction was accomplished, according to the technique described. After the reduction a plaster was applied; this was removed at the end of forty-five days. At that time the loose trochanteric fragment was united to the lateral surface of the trochanter. The dislocation had been overcome, but a slight varus deformity of the femoral neck was present. There was marked periosteal thickening of the femoral diaphysis.

In the roentgenogram taken on February 28, 1944 (Fig. 1-C), there appeared to be a slight increase in the varus position of the neck, suggestive of the beak of a parrot. The diaphysis was thicker. In contrast to the findings in congenital dislocation of the hip, the epiphyseal nucleus was visible on the affected side, but not on the normal side. Roentgenograms taken five months after injury (Figs. 1-D and 1-E) showed complete recovery. The capital epiphyses could be seen on both sides. The slight varus position of the neck and the slight thickening of the shaft were still present. Roentgenograms (Fig. 1-F), taken eight months after treatment, revealed the persistence of varus of the neck.

There was no shortening of the limb. At fourteen months of age the patient began to walk. At the present age of two years and three months, the gait is normal and there is no atrophy of the thigh muscles. The final result is shown in Figure 1-G.

CASE 2. H. C. was born on August 10, 1944, after a hard delivery, during which it was necessary to exert energetic traction on the right lower extremity. A mild shortening of the limb, pain on motion, and prominence of the greater trochanter were noted. Two days later oedema of the thigh was observed. A roentgenogram taken fifteen days after birth (Fig. 2-A) showed the typical fracture-dislocation, with increased distance from the femur to the pelvis and subperiosteal new-bone formation. Treatment was instituted in the usual manner. Upon removal of the spica at the end of forty-five days, the condition of the limb had improved. A roentgenogram taken at the end of four months showed complete healing of the fracture. The "parrot-beak" deformity of the neck was noted. On the right side the epiphyseal nucleus was more noticeable than on the healthy side. The affected femoral diaphysis was thickened.

The baby walked at the age of fifteen months, and his development has been completely normal. The roentgenographic findings seventeen months after reduction of the fracture are shown in Figure 2-B.

Two similar cases are at present under treatment, and it is believed that the end results will be as favorable as in the cases reported here.

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PANNER'S METATARSAL DISEASE: A CONDITION OF ASEPTIC NECROSIS SIMULATING MARCH FRACTURE

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Subperiosteal stratification of the distal shaft of a central metatarsal bone is generally regarded as roentgenographic evidence of a march fracture when it first appears, in the absence of distinct recent trauma, in a young infantry recruit who suffers with a painful foot[4]. A similar subperiosteal stratification may be associated with a varying degree of aseptic necrosis of the adult metatarsal head; Watson-Jones has pointed out the resemblance of the latter condition to march fracture. Although the name of Panner is associated with this second condition, Köhler had previously described the thickening of the distal diaphysis[5]; Freiberg's illustrations also show thickening of the distal diaphysis, although this feature was not specifically discussed. The voluminous current American literature on march fracture makes little or no mention of the condition. At an infantry replacement center where several hundred march fractures were seen annually[3,6], the rare occurrence of Panner's disease occasionally caused difficulty in proper diagnosis; this was particularly true in that phase in which the subperiosteal stratification was the predominant roentgenographic feature. Usually the process is somewhat advanced when first seen; in the following case, roentgenographic studies were made early in the course of the disease and its entire cycle is presented roentgenographically.

FIG. 1

FIG. 2

Fig. 1: February 27, 1945. Left metatarsal area of an infantry recruit, aged twenty-five, who was undergoing strenuous training. Roentgenographic findings do not confirm the clinical impression of march fracture.

Fig. 2: April 23, 1945. Subperiosteal stratification, suggestive of an early march fracture, is seen on the third metatarsal shaft distally. Suggestive cystic changes are present in the metatarsal head.

CASE REPORT

In February 1945, one month after induction, an infantry recruit, twenty-five years of age, first complained of pain in the left foot following strenuous training. No known trauma had occurred recently. There was a history of previous mild temporary disability, lasting for a few days, in the summer of 1944,

FIG. 3

FIG. 4

Fig. 3: May 1, 1945. Note the similarity to march fracture of the third metatarsal.
Fig. 4: July 13, 1945. Definite cystic changes are now evident in the third metatarsal head.

FIG. 5

FIG. 6

Fig. 5: September 28, 1945. Oblique views, showing further progress of the process.
Fig. 6: November 13, 1945. Most of the third metatarsal head shows a cystic change.

FIG. 7

December 5, 1945. Oblique view, showing the articular cartilage and subchondral bone, which have become separated from the remainder of the head and have collapsed into the cystic area to produce further deformity in outline of the metatarsal head.

after a wedge dropped on his left foot; no discomfort had occurred in the interim. On February 27, 1945 the attending medical officer ordered a roentgenogram (Fig. 1), which did not confirm the clinical diagnosis of march fracture. Subsequent roentgenograms (Figs. 2 and 3) appeared somewhat compatible with the clinical diagnosis of march fracture of the left third metatarsal. The institution of routine treatment for march fracture at this time, with metal reinforcement of the sole of the shoe, did not relieve the symptoms.

Because of the persistence of pain and limitation of motion in the left third metatarsophalangeal joint, the patient was referred to the consultant on arthritis, and later to the orthopaedic consultant, at the Regional Hospital. At this time, roentgenograms showed the typical picture of Panner's disease. Clinical examination of the feet was not remarkable, except for the presence of slight local swelling on the dorsum of the distal left metatarsal area with slight limitation of motion and pain at the left third metatarsophalangeal joint. The blood chemistry, including determinations of serum calcium, phosphorus, and phosphatase, was within normal limits, as were the sedimentation rate, routine blood studies, and urinalysis. Only limitation of activities afforded symptomatic relief. The general physical condition of the patient was excellent. When last seen, in December 1945, local examination disclosed moderate thickening about the left third metatarsophalangeal joint and pain on extremes of motion at this joint, with slight restriction of motion.

DISCUSSION

The cystic changes in the metatarsal head may not always be so marked as in the present case. The differentiation of Panner's disease from march fracture is essential from both prognostic and therapeutic viewpoints. A certain rigidity and mild pain persist in the affected metatarsophalangeal joint as a result of aseptic necrosis of the metatarsal head; patients with this condition do not respond to the ambulatory type of treatment which has proved satisfactory in most march fractures.

The occurrence of aseptic necrosis in the adult metatarsal head is less frequent than in the juvenile case, and it is not so generally recognized. Panner was not aware of the origin of the condition in an adult, and expressed the opinion that it began in childhood and progressed without symptoms. In the usual adult case, early roentgenograms have not been taken and, since the same condition was known in the juvenile, it is not difficult to understand the basis for Panner's conclusions. Gaitskell reported one case in which roentgenographic changes first occurred in adult life; the same is true in the present case.

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THE SUPRACONDYLOID PROCESS OF THE HUMERUS

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The presence of an anomalous bony spur on the medial aspect of the lower third of the humerus in approximately 1 per cent. of people of European ancestry has long been known to anatomists, anthropologists, and zoologists. However, its occurrence with a well-defined clinical syndrome has received very little attention in the medical literature of the English-speaking countries. The present article reports three cases encountered at an Army General Hospital, with a review of the anatomy and pathological findings discussed in the literature.

ANATOMY

This bony spur (variously named the supracondylar, epicondylic, or supra-epitrochlear process by different authors) occurs as a beaklike process, which arises from five to seven centimeters above the medial epicondyle of the humerus and extends obliquely downward and forward in a medial direction. The apex of the process is roughened and, in some cases, joined to the medial epicondyle by a band of fibrous tissue[2,9,10,11].

Through the foramen thus formed by the supracondyloid process and its ligamentous band, the median nerve usually passes. Frequently it is accompanied by the brachial artery or one of its branches[2], and by the radial or ulnar artery (Fig. 1). The process may afford insertion to a persistent lower part of the coracobrachialis[9]. Usually the pronator teres has an anomalous origin from the process, when present, as well as from the fibrous band [6,9], and overlies the median nerve and brachial artery at this point.

The supracondyloid process and its ligamentous band constitute the homologue in a rudimentary form of a bony canal, present in many animals. McGregor states: "An entepicondylar (supracondyloid) foramen is present in many extinct and living reptiles and in many mammals,—especially the mammalian orders which are archaic and primitive. Most marsupials have it, and it is present in many carnivores,—for example, the cat. Among Primates it is found in most lemurs, tarsies, and in many, but not all, American monkeys. Old-World monkeys do not have it, but among anthropoid apes it has been found occasionally in the orangutan and gorilla."

In this connection, Dwight reported a case of a bony supracondyloid foramen, found in the dissection of the body of a middle-aged female. A bony supracondyloid foramen has been reported by Cunningham[1] in a full-term stillborn infant.

INCIDENCE AND SYMPTOMS

For a number of years anthropologists have looked for and recorded the incidence of the supracondyloid process among primitive peoples and racial groups[5]. In the State of Mississippi, Terry[14] reported finding a supracondyloid process in 6 of 515 whites, but only once in 1,000 negroes. From these and from subsequent studies, he concluded that the supracondyloid variation appeared markedly among people of European stock and was probably indicative of fundamental differences in origin of the human races[15]. Testut reported finding the anomaly in 1 per cent. of his specimens, and Gruber in 2.7 per cent. A familial incidence has been reported in numerous instances[8,13].

The close anatomical relationship of the median nerve to the supracondyloid process would lead one to expect occasional sensory or motor disturbances in that nerve. In 1929 Solieri reported a nineteen-year-old male who had median-nerve symptoms,—severe paraesthesia and hypaesthesia of the hand and fingers, caused by the presence of the supracondyloid process. Following operation in this case the neuralgia disappeared immediately,

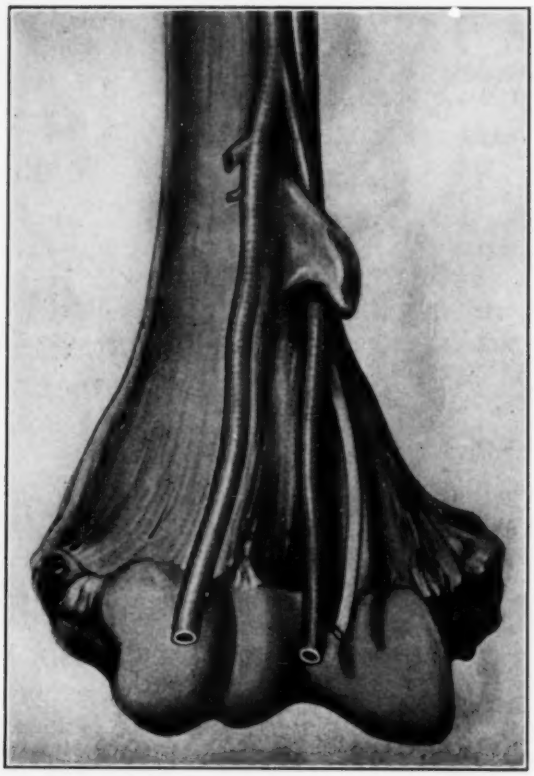

FIG. 1

FIG. 2

Fig. 1: Shows the relationship to the supracondyloid process of the brachial artery, its branches, and the median nerve. (*Reproduced, by permission, from La Chirurgia degli Organi di Movimento,* **24**: 123, 1938.)

Fig. 2: Roentgenogram of Mandruzzato's Case 4, showing calcified ligamentous band extending from the supracondyloid process to the medial epicondyle. (*Reproduced, by permission, from La Chirurgia degli Organi di Movimento,* **24**: 128, 1938.)

but it returned in a milder form six months later. A bony spur regenerated from the periosteum in this case.

In 1938 Mandruzzato reported five cases. Cases 1, 2, and 3 were patients in whom the supracondyloid process was an incidental finding, noted on physical or roentgenographic examinations for other conditions. The bony spurs were asymptomatic. Mandruzzato's Case 4 was an Italian male, twenty-six years of age, who complained of weakness of the left arm and tingling in the area of the median nerve. This pain became so severe that the patient was unable to work. Complete extension of the elbow and pronation of the forearm increased the pain. The supracondyloid process was palpable six centimeters above the elbow, and there was slight hypaesthesia to pain, touch, and temperature change in the area of the median nerve, with loss in strength of the grip of the hand. Roentgenograms showed the triangular bony spur to be in the usual location (Fig. 2). Mandruzzato stated that on the film one could see clearly a shadow, which extended from the apex of the bony process downward in a curve to its attachment at the margin of the epitrochlear. He felt there was no doubt that this band of tissue was attached to the supracondyloid process. His diagnosis was neuritis of the median nerve, due to the supratrochlear process. At operation Mandruzzato found the patient's median nerve to be in close contact with the supratrochlear fibrous band and with the pronator teres. The bony spur was dissected with its periosteum. The patient's symptoms were relieved and there was no recurrence.

In Mandruzzato's Case 5 a woman, thirty-three years old, complained of severe pain in the area of the median-nerve distribution of the right forearm and hand, aggravated by

even slight movement of the elbow. Thirty years previously, at the age of three, she had injured the right elbow. Three months before admission her right arm was injured, and she subsequently noticed lancinating pain along the flexor surface of the forearm. On examination, a bony spur was found on the medial aspect of the right arm, five centimeters above the epitrochlear. Below it, he states, was a nearly round nodule of irregular outline, hard in consistency and producing a crunching sound when rubbed against the supra-epitrochlear process; all movements of the nodule in the area examined produced pain, which followed the distribution of the median nerve, pain also going up toward the shoulder. Roentgenograms disclosed an old fracture near the apex of the supratrochlear process. This finding was confirmed at operation, when the spur and the fragments were excised. There was complete relief after the operation.

In both patients operated upon by Mandruzzato, the anomaly of the pronator teres was noted, and he concluded that the bony prominence had great effect on the median nerve because, during muscle contraction of the pronator teres, it is impinged by compression on the supra-epitrochlear canal. He recommended removing the periosteum, together with a part of the muscle fibers of the pronator teres, to avoid maintaining irritation to the median nerve by contraction of the muscle.

CASE REPORTS

Three patients with the supracondyloid process have come under our observation.

Case 1. A lieutenant colonel in the Medical Corps had noted for many years the presence of a small bony prominence on the medial aspect of his left arm, six centimeters above the epicondyle. There was no history of injury, and no associated symptoms. On roentgenographic examination, a small but well-developed supracondyloid process was found. Routine anteroposterior and lateral films failed to reveal the spur, but the oblique film showed it clearly (Figs. 3-A and 3-B).

Fig. 3-A

Fig. 3-B

Fig. 3-A: Case 1. Oblique view.
Fig. 3-B: Routine anteroposterior view fails to show the supracondyloid spur, which was demonstrated in Fig. 3-A.

FIG. 5-B

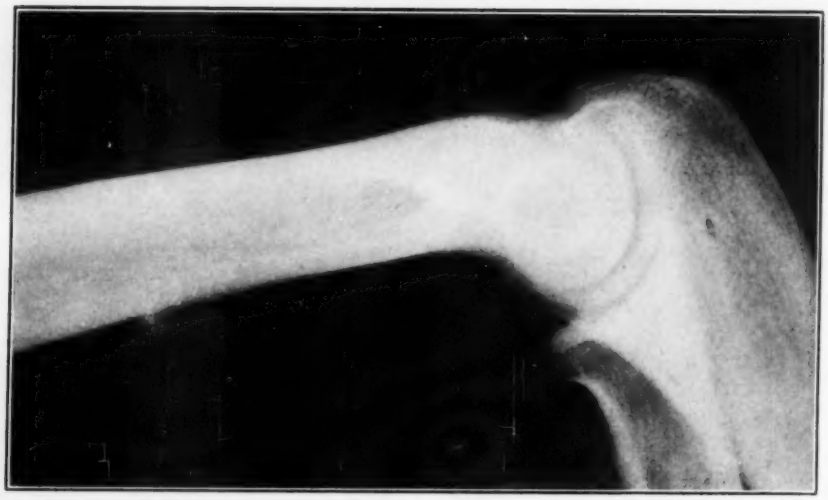

FIG. 5-A

Case 3. Anteroposterior and lateral views.

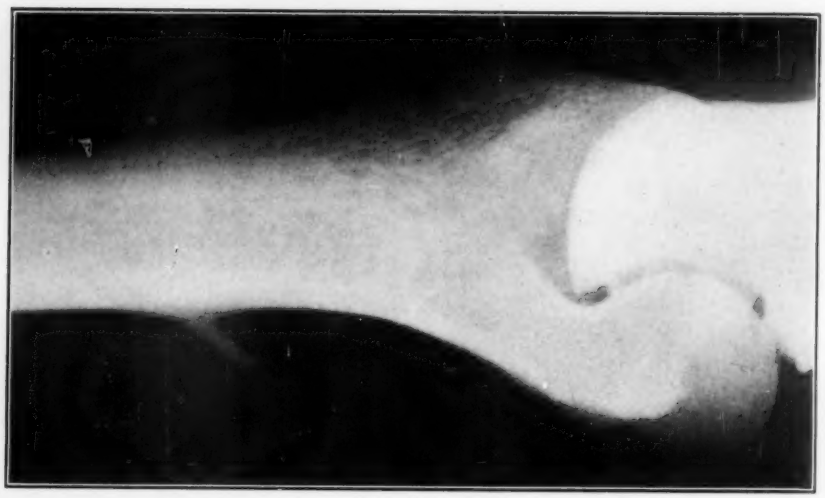

FIG. 4

Case 2. Oblique view shows supracondyloid bony spur of humerus.

CASE 2. A private first class, thirty-two years of age, was seen in consultation in the Orthopaedic Clinic, complaining of pain in the right arm and forearm, radiating to the median-nerve area in the hand. There was no history of injury; the pain was not very severe. A bony spur was palpable on the medial and anterior aspects of the right humerus, 5.5 centimeters above the elbow. Pressure beneath it reproduced this pain. Routine anteroposterior and lateral roentgenograms failed to show the bony spur, but it was well visualized on an oblique film (Fig. 4). Because of the mild nature of the symptoms and the absence of atrophy or hypaesthesia, operation was not advised.

CASE 3. A nineteen-year old private in the Infantry complained of pain, weakness, and numbness of the left arm and hand, and of pain in the left shoulder. One month before admission to the hospital, he had been injured by the blast of an exploding artillery shell, which caused him to fall on his left shoulder. There was swelling and limitation of motion at the shoulder, but roentgenograms showed no evidence of bone injury or dislocation of the shoulder. One month later he was still complaining of pain in the left shoulder, left arm, and forearm, radiating to the area of median-nerve distribution in the hand. This pain was severe, and was aggravated by extending the elbow and pronating the forearm. There was a normal range of motion at the shoulder, and no evidence of injury. Six centimeters above the medial epicondyle a bony spur was palpable, and pressure in this area caused paraesthesia in the median-nerve distribution, duplicating the patient's complaint. There was no hypaesthesia and no evidence of motor impairment of the nerve. Roentgenograms confirmed the presence of the supracondyloid bony spur on the anteromedial aspect of the lower part of the humerus. At operation, the spur was found to have an overlying bursa, measuring one centimeter in diameter. The branchial artery and the median nerve passed beneath the spur, to which was attached a slip of muscle from the pronator teres. The bony spur and its periosteum were resected in the manner recommended by Solieri and by Mandruzzato. The patient was immediately relieved of all pain, and was sent to general duty twenty-eight days after the operation (Figs. 5-A and 5-B).

SUMMARY AND CONCLUSIONS

1. The supracondyloid process, when present, is often associated with a tendinous band, which is attached to the medial epicondyle, and with an anomalous origin of the pronator teres.

2. The supracondyloid process can cause a syndrome characterized by pain, radiating from the shoulder to the median-nerve area of the hand. This pain is increased by pronation of the extended forearm.

3. The diagnosis is easily made by palpation, but routine anteroposterior or lateral roentgenograms may fail to show the spur, because of its position on the anteromedial aspect of the bone. An oblique view may be required.

4. Solieri and Mandruzzato have reported three cases in which relief followed resection, and one additional case of resection is reported here.

5. In resection of the bony spur, it is emphasized that removal of the periosteum of the spur and the binding fibers of the pronator teres should be done to prevent regeneration of the spur and the recurrence of symptoms.

NOTE: The authors wish to express their appreciation to Dr. J. H. McGregor, Professor Emeritus, Department of Zoology, Columbia University, for his aid in preparing this article.

Photography was done by Staff Sergeant Carl V. Smith, Medical Detachment, Woodrow Wilson General Hospital, Staunton, Virginia.

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OSTEOTOMY OF THE LUMBAR SPINE FOR CORRECTION OF KYPHOSIS IN A CASE OF ANKYLOSING SPONDYLARTHRITIS

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INTRODUCTION

Gradual or manipulative correction of kyphosis in cases of advanced ankylopoietic spondylarthritis has been widely employed for many years, with discouraging results. Corrections have been uniformly incomplete; they were not without danger; and eventually the deformity nearly always recurred. The roentgenograms and photographs of a patient suffering from this disease are shown in Figures 1-A, 1-B, 2, and 5-A. This man's urgent wish to become erect and his otherwise healthy, vigorous condition prompted the author to devise a method of operative correction through section of both the anterior and posterior elements of the vertebral column. The operation, when performed upon the cadaver, gave promise of being safe and feasible; and it proved to be effective in achieving correction. It was then successfully performed upon this patient; satisfactory correction

FIG. 1-A

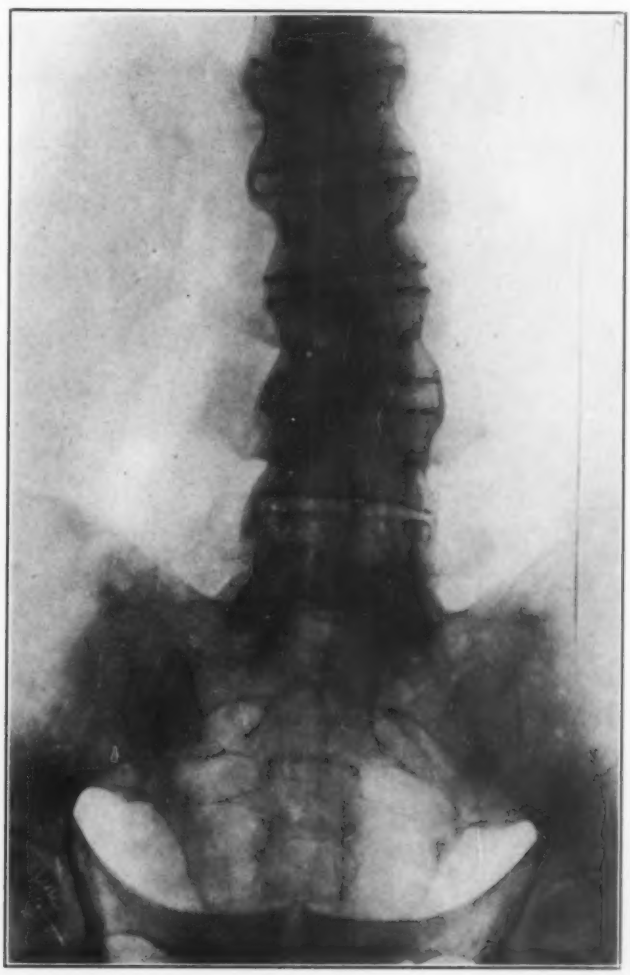

FIG. 1-B

Lateral and anteroposterior views of the vertebral column in 1940.

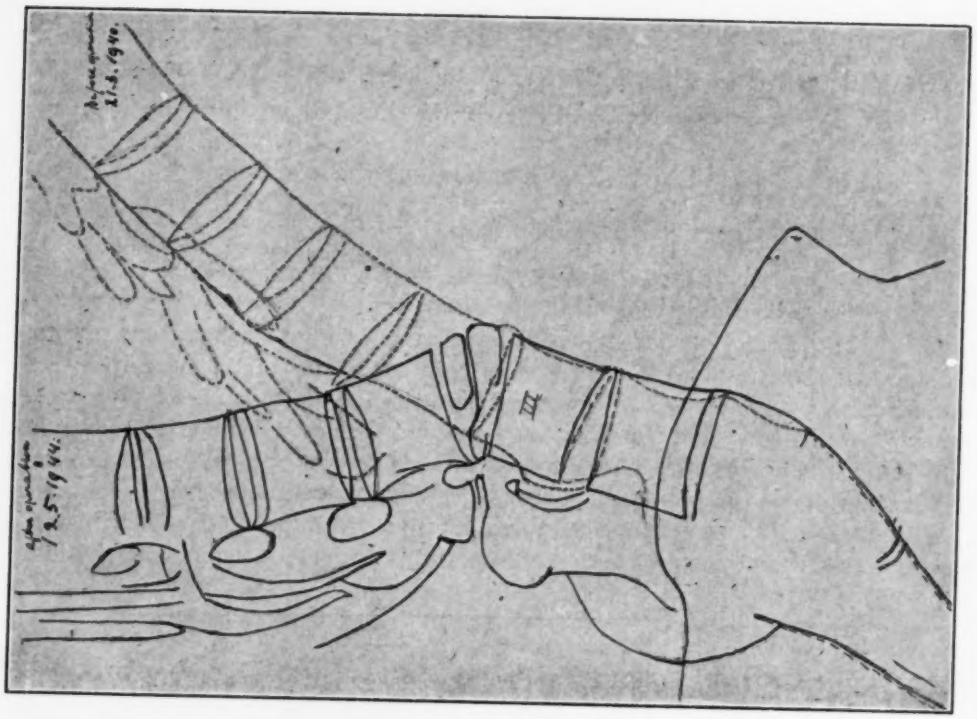

FIG. 4

Outlines of vertebral column, before and after operation.

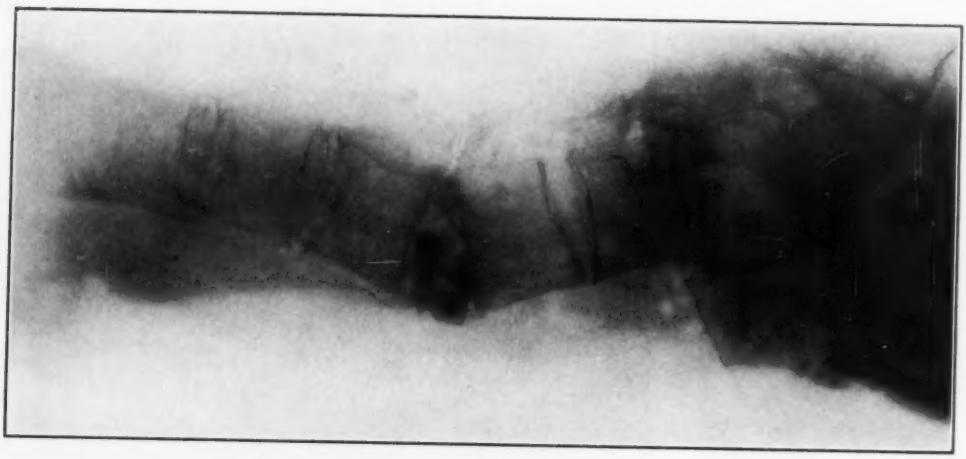

FIG. 3

Fig. 3: Three months after operation.

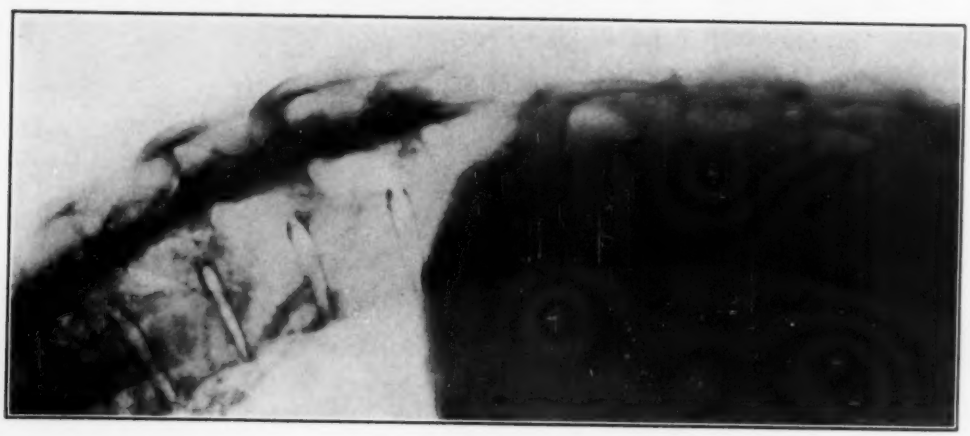

FIG. 2

Fig. 2: Appearance of the vertebral column in 1944, a short time before operation.

was obtained (Figs. 3 and 5-B) without untoward incident; and the result more than two years later was gratifying (Fig. 7).

PATHOLOGICAL FACTORS

A study of the roentgenograms indicated bony ankylosis of the posterior articulations between the thoracolumbar and lumbar vertebrae, as well as ossification of the anterior longitudinal and interspinal ligaments throughout the lumbar region and part of the thoracic region. That ankylosis was not complete was apparent, since the patient was more erect in the morning than in the evening. He was conscious of this change of posture, which is one not uncommonly observed, even in the more advanced stages of the disease[5]. Ankylosis proved to be such, however, that nothing could be accomplished toward correction of the deformity by non-operative means,—including exercises, suspension, recumbency in extension, a plaster jacket, and a corset. (Actually, as was demonstrated later at operation, extensive fibrosis and partial ossification of ligaments were found posteriorly, making identification of bony structures difficult. Anteriorly about the vertebral bodies, the ossified portion of the ligament was found to vary from the thickness of thin paper to that of thick paper.) In view of the pathological changes, it seemed necessary for successful correction that both the anterior and posterior elements of the vertebral column be freed, since each was involved in the ankylosing process.

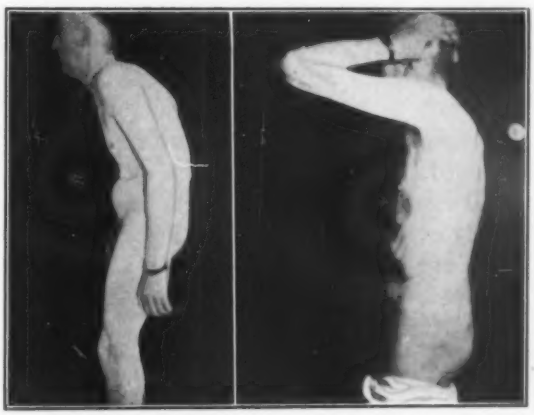

FIG. 5-A FIG. 5-B

Fig. 5-A: Before operation. Patient straightens himself as much as possible, bending his knees so as to shift the center of gravity backward.

Fig. 5-B: After operation. The photograph again shows a compensatory lordosis under the kyphosis.

MECHANICAL FACTORS

Abnormal skeletal curvature can be corrected by osteotomy, if the involved bone is surgically accessible, and if the nature of the disease producing the curvature and the patient's general condition permit. A compensatory angulation at the site of osteotomy corrects the malalignment. The osteotomy may be performed at several points or, preferably, at one. If the ankylosed vertebral column is considered as one bone, the use of the term osteotomy seems justified to describe surgical section of the column for the purpose of correcting deformity. The site and type of osteotomy must be such that injury to the spinal cord and its nerves will be avoided, and that sufficient correction of the deformity will be obtained. The axis of motion, or hinge point, during angulation of the osteotomized column will be at the posteriormost point of contact of the vertebral bodies immediately above and below the site of osteotomy,—that is, their adjacent posterior borders. A sufficient quantity of bone posterior to the vertebral canal must be removed, and the intervertebral disc must be sectioned anteriorly in order to permit correction. Theoretically, when the vertebral column has been sectioned in this manner and an adequate compensatory anterior angulation has been obtained, the sectioned disc should gape anteriorly and the margins of the osteotomized neural arches should come together posteriorly. This is exactly what occurred in the cadaver,—the sections of the divided vertebral column moved upon each other in flexion and extension about the adjacent posterior borders of the freed vertebral bodies as if on a hinge.

The second and third lumbar vertebrae are favorable sites of osteotomy, since they lie

FIG. 4

Outlines of vertebral column, before and after operation.

Fig. 2: Appearance of the vertebral column in 1944, a short time before operation.
Fig. 3: Three months after operation.

caudal to the spinal cord, are outside the more rigid thoracic region, and are sufficiently near the mid-point of the kyphotic curve.

A roentgenographic tracing of the curve of the patient's vertebral column, used as a pattern, showed that the removal of 3.5 centimeters of the extreme dorsal bony elements would allow a gap on the ventral side of the column sufficient for correction. Allowing for the roentgenographic magnification, a little less bone could be removed in reality.

Forward displacement, during correction, of the vertebra above the osteotomy onto the vertebra below appears to be possible. Following extensive laminectomies in individuals with weak muscles and lax ligaments, especially if the posterior articulations are weakened or removed, spondylolisthesis may develop. This is generally of slight degree. It was thought that in this case the danger could not be very great, because the posterior longitudinal ligament would be thick and hard. To provide against this complication, the posterior ligamentous elements of the disc—including the posterior longitudinal ligament—must not be divided. Actually, these posterior ligaments were left intact, both in the operation upon the cadaver and that upon the patient, and no forward displacement occurred.

Following osteotomy in the cadaver, the dura was opened and the cauda equina was widely exposed. The vertebral column was then angulated anteriorly and posteriorly, and the nerve roots were inspected. No encroachment upon the lumen of the vertebral canal occurred, and the spinal cord and nerve roots moved freely in the unchanged meningeal compartment.

OPERATIVE TECHNIQUE

The operation must be performed in two stages. The first stage involves the removal of the laminae of the second lumbar vertebra and of the posterior articulations between that and the third lumbar vertebra. The second stage, performed through an anterior approach, is concerned with the excision of the second lumbar intervertebral disc, the angulation of the column, and the fixing of bone grafts in the gap between the two vertebrae.

Stage I

The first stage, performed January 26, 1944, can hardly be claimed to be a new operation, although the combined excision of the laminae and the articulations on both sides is not a common one. Identification of the spinous processes of the first, second, and third lumbar vertebrae proved especially difficult, because of the ossification of the interspinal ligaments, so that roentgenographic localization was necessary. Local anaesthesia (novocain and adrenalin) was used, with the patient lying prone, propped with pillows. The three spinous processes were laid bare and excised. Difficulty was encountered in identifying and freeing the laminae and articulations and in exposing the intervertebral notches, owing to the formation of fibrous tissue and to partial ossification. Hemorrhage was also present, and its control required time and patience. Following complete laminectomy of the second lumbar vertebra, the articulations on each side between the second and third lumbar vertebrae were identified; and the four articular processes were completely removed, special care being taken to avoid injury to the roots, ganglia, and nerves lying immediately anterior in the intervertebral notches.

The postoperative course was uneventful. The temperature did not rise above 38.1 degrees centigrade. Two weeks after operation, the hemoglobin was 85 per cent., erythrocytes 4,100,000, leukocytes 9,500, and thrombocytes normal. The blood pressure was 130/80.

Stage II

The second stage was performed on February 11, 1944, under general anaesthesia. With the patient lying on the right side, a transverse abdominal incision, similar to that of Péan, was made a little above the umbilicus, opposite the second lumbar intervertebral disc.

This incision can easily be made large enough, with slight damage to muscles. Following reflection and retraction of the peritoneum and its contents, a large part of the lumbar vertebral column could be seen quite well, as is often observed in operations for horseshoe kidney and in extraperitoneal lumbar ganglionectomy. The approach from the left is easier than that from the right, for the aorta and the vena cava, lying somewhat to the right, can be displaced in that direction, making possible direct palpation of both sides and the front of the vertebral bodies. The lumbar arteries and veins traverse the vertebral bodies midway between the discs, and can readily be avoided. Because the disc is avascular, hemorrhage was avoided. The disc was exposed and excochleated throughout most of its extent anteriorly, but its posterior wall was not touched, as previously emphasized.

The patient was then carefully placed in the supine position by turning the operating table on its long axis. As the supporting pillows were removed, the back was gradually released and, through the action of gravity, was straightened until it rested upon the table; thus the deformity was satisfactorily corrected. The lateral position was then restored by turning the table; and pieces of bone, removed from the tibia with the motor saw, were packed into the gap which had appeared between the bodies of the second and third lumbar vertebrae. The wound was closed.

A double plaster spica from axillae to

FIG. 6

Vertebral column in 1945, one year after operation.

FIG. 7

Roentgenogram taken two years after operation.

knees was then applied, as the patient lay supine on a flat metal band. This band rested at one end on the head of the operating table; at the other end it was supported by an assistant. When the plaster had hardened, the band was removed.

Again the postoperative course was uneventful. The temperature did not rise above 37.8 degrees centigrade. During the first day, the pulse rose to 130 per minute; the minimum blood pressure was 95/75. There was slight subcutaneous emphysema of the scrotum. No neurological disturbances were observed.

PATHOLOGICAL EXAMINATION

The pathological examination (made by Dr. Rudolf Van Dam) was reported as follows: "Histologically the pieces of intervertebral disc are found to consist of normal fibrocartilage, which does not contain many cells and in places gives the impression of being somewhat degenerated cystically. This latter finding is not quite clear, however. There is no proliferation in the blood vessels nor of the connective tissue. There were a few pieces of bony tissue [of the anterior longitudinal ligament], of which a section was not made."

AFTER-CARE

The patient remained recumbent in the plaster spica for three months. Lateral and stereoscopic anteroposterior roentgenograms were then made (Fig. 3), after which a plaster jacket was applied, and the patient was allowed gradually to become ambulatory. He was discharged to his home three and one-half months after the operation. The full jacket was removed at the end of six months, after which he wore a light one for several months longer as a precaution.

END RESULTS

Roentgenograms taken eleven and twenty-five months after operation are shown in Figures 6 and 7, respectively; the photograph at the completion of treatment is shown in Figure 5-B. The patient is completely satisfied. No return of the deformity has occurred during two years.

LITERATURE

In operating upon the lumbar vertebral bodies, Huc used a variation of the method first described by Treves, in 1892. The approach was made through an incision along the lateral border of the erector spinae. The transverse processes were resected, and access to the bodies was thus obtained. The roots of the lumbar plexus intervened posteriorly, however, and the psoas intervened anteriorly, so that any procedure through this approach was very difficult.

Ito, Tsuchiya, and Asami, in 1934, described operative procedures on tuberculous thoracic and lumbar bodies, in ten cases. These authors had been impressed by the wide exposure possible in lumbar-sympathetic ganglionectomy. The thoracic approach is difficult, although Peet's operation is encouraging.

The posterior osteotomy of Smith-Petersen, for the correction of deformity arising in this disease, did not come to the author's attention until December 1945, since access to current foreign literature was impossible in the Netherlands during the war years. The six cases of Smith-Petersen show that the anterior portion of the vertebral column gave way sufficiently, following excisions of the posterior structures alone. In the author's case, ossification of the anterior longitudinal ligament apparently prevented correction by simple supine recumbency, following the first stage of the procedure. Great force was not applied, however. Only after section of the disc in the second stage was correction obtained. An advantage of the method of Smith-Petersen is, of course, that it can be performed in one operation. Time and further investigation may disclose which of these

procedures is more suitable, not only in cases of kyphosis but also in other deformities of the vertebral column.

CASE HISTORY

G.P., a cook and restaurant keeper, born in 1900, was well until 1937, when he was struck by a motor car. He was admitted to a hospital in Amsterdam, where the diagnosis of fractured vertebra was made. The roentgenograms taken at that time cannot be found; subsequent films show no evidence of a fracture. After six weeks in the hospital he was discharged; his back was stiff, and he bent forward as he walked. Later the condition was diagnosed as ankylopoietic spondylarthritis, and he was given roentgenotherapy and "injections". He became free of pain in 1939.

In 1940 he was referred to the author for correction of the kyphotic deformity. The erythrocyte sedimentation rate (Westergren) was 46 millimeters per hour. The roentgenograms and photograph taken at that time are shown in Figures 1-A, 1-B, and 5-A. The patient was lean, but quite healthy. No other joints were affected. He was given a course of gold therapy. The sedimentation rate later fell to 29 millimeters; by 1944 it was 14 millimeters per hour.

Attempts were made to correct the deformity by exercises, traction, and recumbency in extension; supports included plaster jackets and a corset. These did not avail, except that the corset gave indispensable support. He complained constantly of the pressure of the corset, although he could not work without it. He repeatedly requested surgical intervention to correct the deformity.

The first stage of the operation was performed January 26, 1944; the second stage on February 11, 1944.

Since the operation, the patient has been under observation for two years. He has remained symptom-free as far as his back is concerned, and he is satisfied with the result obtained.

In October 1944 he suffered an attack of rheumatoid arthritis with involvement of the left hip and shoulder, which cleared up during the administration of salicylates and warmth. By February 1945 he was again well. The sedimentation rate fell from 23 millimeters, in October 1944, to 13 millimeters. It is probable that the poor nutrition which prevailed in the Netherlands, together with the lack of fuel and a great sorrow in his family, were responsible for this attack. There has been no return of the deformity.

DISCUSSION

The first stage of the operation was rather laborious and tedious, requiring much patience, whereas the second operation went more smoothly in all respects than had been expected, especially as regards the loss of blood. Nevertheless, whenever it is proposed to perform the operation, all features will have to be weighed and checked extremely carefully, step by step. Every phase of the operation is under control, however, and it can be interrupted during any phase. The indications for it are rare in spondylarthritis: The case must be a resistant one, as far as the vertebral column is concerned; and the patient must be in good health and not too old. The condition of the other joints should be considered. It is not an operation to be undertaken lightly. It may be, however, that modifications of the operation, in either of the two stages, can be applied in other cases. This may be possible, for example, with kyphoses of a different nature, as in the congenital form, when pressure of the medulla on the curvature may lead to paralysis. Laminectomy, which is sometimes performed in the latter group, is really an illogical operation, unless the kyphosis is removed. In certain other cases of kyphosis and also of scoliosis, the two-stage operation may be considered, but it is seldom indicated. In regard to scoliosis, the operation has so far been performed only on the lumbar region and on cadavera; the results are encouraging.

The easy accessibility of the lumbar vertebral bodies and discs suggests the applicability of this operation in rare cases of vertebral fracture and of isolated tumors. It seems quite possible that, in hernia of the disc, the entire disc can be removed and replaced by bone grafts, as in Stage II. These considerations raise the question of whether the technique of the operation cannot be further improved—especially as regards details in the fixation of the transplanted bone—and its applications extended.

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RECURRENT DISLOCATION OF THE FIRST CARPOMETACARPAL JOINT REPAIRED BY FUNCTIONAL TENODESIS

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Recurrent dislocation between the base of the first metacarpal bone and the greater multangular is rare, and it has not been mentioned until recently in textbooks. Bennett's fracture complicated by dislocation in this joint, or acute dislocation with fracture of the base of the first metacarpal, is more common. In the case described here, there had been an acute dislocation in this joint, which had been reduced and had recurred, and the reduction could not be maintained by the closed methods of treatment.

A review of the literature disclosed three procedures which have been used for this condition. Bunnell has described a method of "lashing the metacarpal to the trapezium with a strip of tendon or fascia through drillholes". Slocum reported one case in which he used a tendon graft from the palmaris longus, pulling it through volar drill holes made in the base of the thumb and the greater multangular. Eggers described a case in which he used the lateral portion of the tendon of the extensor carpi radialis longus, dividing it, and inserting this divided band into the base of the metacarpal of the thumb through drill holes. The operation described here offers a new approach to this problem.

CASE REPORT

G. G., a twenty-two-year-old male, was first examined on February 15, 1945. About one year before, he slipped on an icy pavement and fell, landing with a considerable amount of his weight on his extended right arm and the dorsiflexed hand. The palm did not touch the pavement, but only the tips of the extended fingers and thumb. He had severe pain and noticed deformity of the first carpometacarpal joint. The dislocation was reduced and a plaster bandage was applied for three weeks. At the end of this period the patient resumed normal activities, but the bone soon became displaced again. At the time of examination, his complaints were of pain in his thumb and inability to use his hand for working.

Physical examination showed an apparent deformity on the dorsum of the right hand, corresponding to the carpometacarpal joint. The patient demonstrated that he was able to reduce the dislocation, but that the bone would immediately become displaced again. The examiner was also able to effect reduction without difficulty, but noted that the bone would snap out again, with a painful crepitation. The intrinsic and extrinsic muscles of the hand showed no abnormalities.

Roentgenographic films in the anteroposterior, lateral, and oblique planes showed a dislocation of the metacarpal bone over the greater multangular (Fig. 1).

The operation to be described was performed on February 18, 1945, at Polyclinic Medical School and Hospital. This patient returned to his regular work four weeks after the operation. He was seen at intervals thereafter; and at the time of the last examination on April 12, 1946, fourteen months after the operation, he had no complaints. The function of the thumb was satisfactory and no impairment could be detected in the action of the extensor pollicis brevis (Fig. 2).

In devising this operation, the author tried to apply a method by which a living tendon transplant would support a capsular repair in order to maintain the corrected position of the dislocated bones. In selecting the tendon, the following points had to be considered:

1. The tendon should have a logical anatomical course to justify its selection.
2. The function of the muscle should actively hold the involved bone in place.

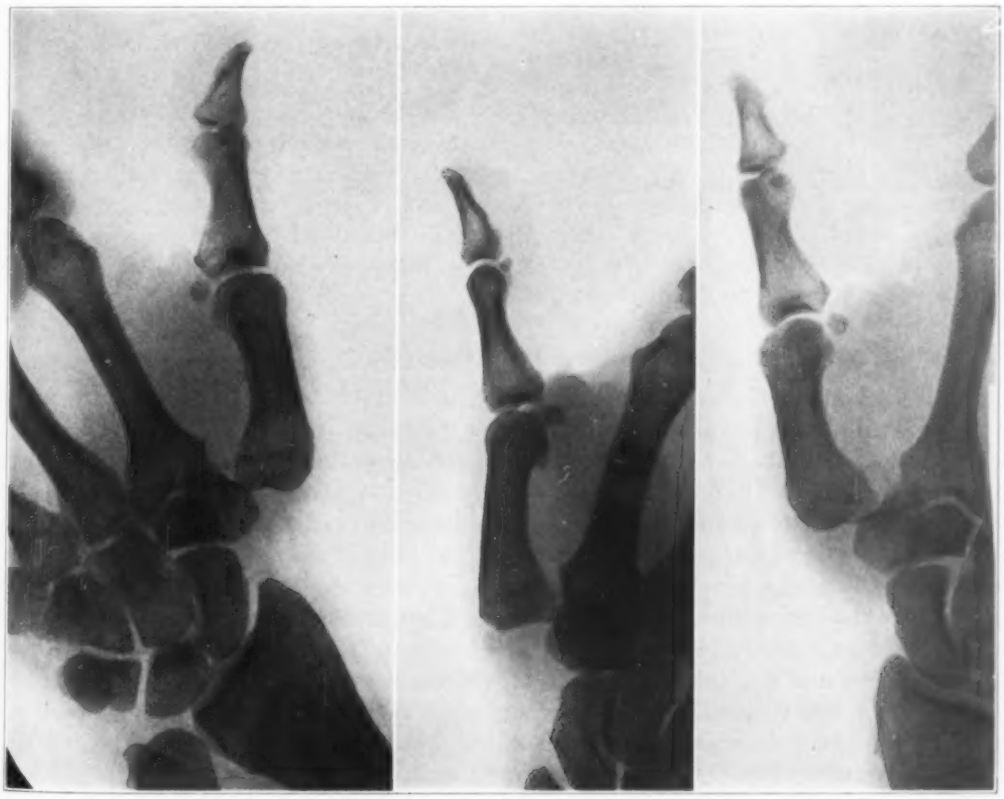

FIG. 1

Roentgenograms show the dislocation of the first metacarpal over the greater multangular.

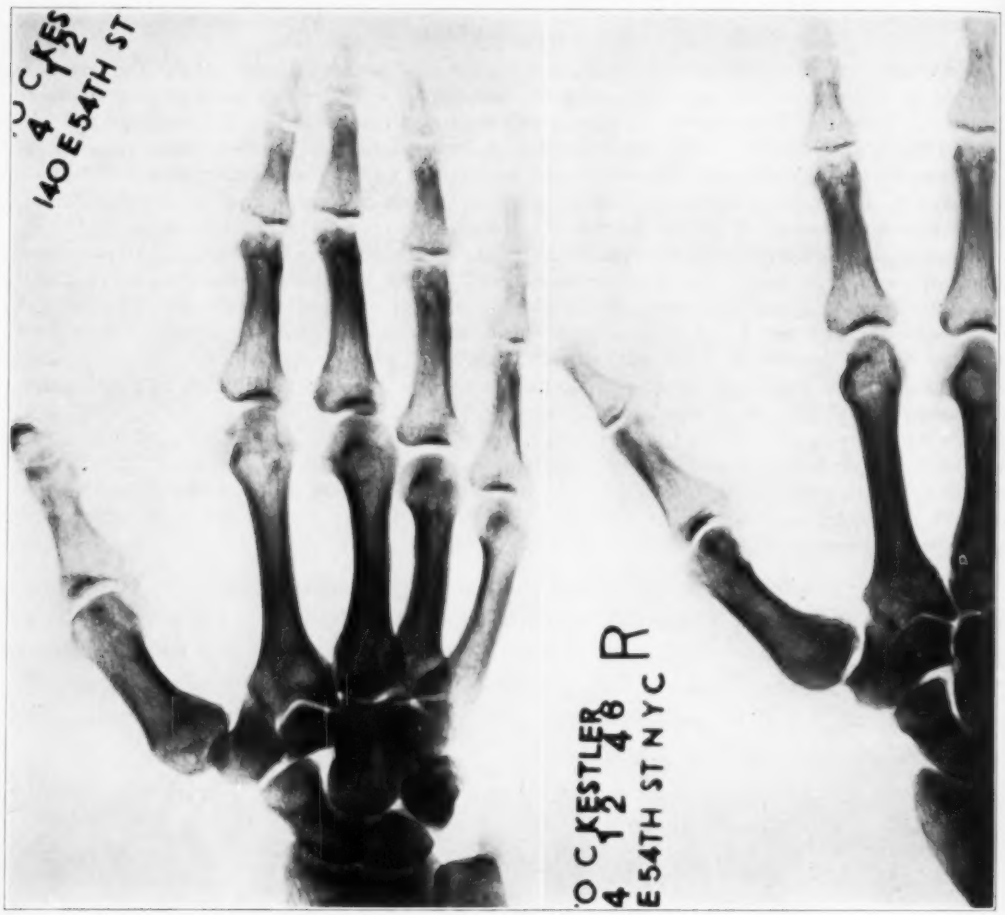

FIG. 2

Anteroposterior and oblique roentgenograms, fourteen months after the operation, show what may be considered a satisfactory end result.

3. The procedure should not interfere with the original function of the tendon. These requirements were fulfilled in the case reported.

OPERATIVE PROCEDURE

With the hand in neutral position, a curved incision was made over the joint between the base of the first metacarpal and the greater multangular (Fig. 3). The incision was about two and one-half inches long, with the convexity to the radial side. By this lateral approach the injury to the dorsal branch of the radial artery could be avoided. The tendon of the extensor pollicis brevis was identified and divided about one-quarter inch proximally to the proximal end of the greater multangular. The base of the first metacarpal bone and the greater multangular were exposed by a sharp periosteal elevator. A drill hole was made in the base of the first metacarpal with a hand drill, and another in the greater multangular with a curved awl. Both holes were enlarged by introducing a wider awl. The distal portion of the tendon of the extensor pollicis brevis was drawn through both holes (Fig. 4). The dislocation was then reduced, and the capsule was sutured. The distal portion of the tendon, which had been drawn through the holes, was sutured to the proximal end of the tendon. Other structures were closed routinely, and anterior and posterior splints were applied to hold the thumb in abduction for three weeks.

Although this procedure was completely satisfactory in this case, after making dis-

FIG. 3

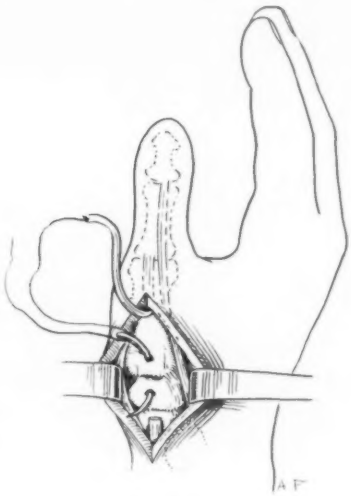

FIG. 4

FIG. 5

Fig. 3: A curved incision is made, with the hand in neutral position.
Fig. 4: The distal portion of the extensor pollicis brevis tendon is pulled through the drill holes in the base of the metacarpal and the hole in the greater multangular.
Fig. 5: The distal portion of the abductor pollicis longus tendon is pulled through the holes in the greater multangular.

sections for the study of the function of the muscles of this area, the author feels that the use of the abductor pollicis longus would be more physiological than the use of the extensor pollicis brevis. When the abductor pollicis longus is used, a hole is tunneled through the greater multangular with an awl, and the distal portion of the cut tendon (Fig. 5) is drawn through and united with the proximal portion.

The following reasons are offered for the use of the abductor pollicis longus:

1. The abductor pollicis longus is attached to the base of the metacarpal; therefore it may be extended through the hole made in the greater multangular.

2. The function of this muscle, with its normal pull, is much more adequate in keeping the reduced metacarpal bone in place.

This procedure would be called transposition and extension of the insertion of the tendon of the abductor pollicis longus.

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NON-UNION OF THE ISCHIAL TUBEROSITY ASSOCIATED WITH EPIPHYSITIS VERTEBRAE

Report of a Case

BY LIEUTENANT COMMANDER WALTER SCOTT

Medical Corps, United States Naval Reserve

McMaster[1] recently reported a case in which the secondary ossification center of the ischium had failed to fuse with the parent structure. His patient was a nineteen-year-old Marine, whose symptoms were recurrent and were localized to the hip area; apparently no other abnormal findings were disclosed by the physical examination or the laboratory data.

Recently a similar case was discovered which, in addition to the ischial findings, showed other signs of osteochondritic dysfunction. Because of these associated changes, and because the available literature on this subject is meager, a further discussion of the disease, with the report of an additional case, seems justified.

CASE REPORT

J.E.B., aged twenty-two, a Private First Class in the Marine Corps, was admitted to a United States Naval Hospital on September 23, 1945, just after he had been evacuated from the South Pacific Area. His chief complaint was pain in the thoracic spine.

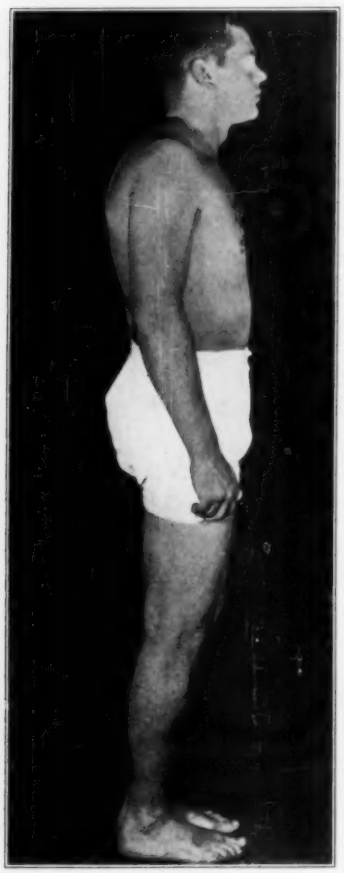

Fig. 1

Showing round-hollow back, with increase in lordosis and forward thrust of the neck.

When the patient was fifteen years of age he had poor posture. At that time he "pulled something" in his right hip while playing baseball, and the hip was sore for about a week. He did not go to bed or have any medical attention; a complete recovery followed.

While engaged in battle as a flame-thrower, in September 1944, the patient's back became painful. He was seen by a medical officer, who found the right leg to be one and one-half inches shorter than the left leg. Treatment consisted of elevation of the right heel and routine physiotherapy; but the patient's complaints persisted, and he was evacuated to this Naval Hospital for further care.

The findings at physical examination were as follows: The patient was a white male, six feet one inch in height, who weighed 192 pounds, and walked with a slight right-sided limp. The hair was of scanty distribution. His shoulders were level; the right side of the pelvis was one and one-half inches lower than the left, because of shortening of the right femur. The tibiae were of equal length. Motions of the spine were within normal limits. There was mild tenderness to heavy tapping along the thoracic spinal muscles.

Four determinations of the basal metabolic rate were taken, several days apart, and they were minus 25, minus 24, minus 10, and minus 4, respectively. Other routine laboratory studies, including the Kahn test, were normal.

The roentgenographic findings were as follows:

1. An anteroposterior view of the pelvis (Fig. 2) showed that the secondary ossification center of the left ischium had failed to fuse. The mass was saucer-shaped and measured 6 by 3.75 by 3.75 centimeters along its triangular margins. Two smaller nodules, ovoid in shape, were visible; one, 2.5 by 1.2 centimeters in size, lay postero-inferiorly to the acetabulum; another was attached to the tip of the main mass, and measured 1 by 1.2 centimeters in size. A few cystic changes and some irregularities were noted in and about the ischium.

2. A lateral view of the thoracic spine (Fig. 3) showed wedging throughout the thoracic area as a result of an old epiphysitis. The typical round-hollow back was evident.

3. Views of the right wrist, the right knee, and the hips were normal in appearance.

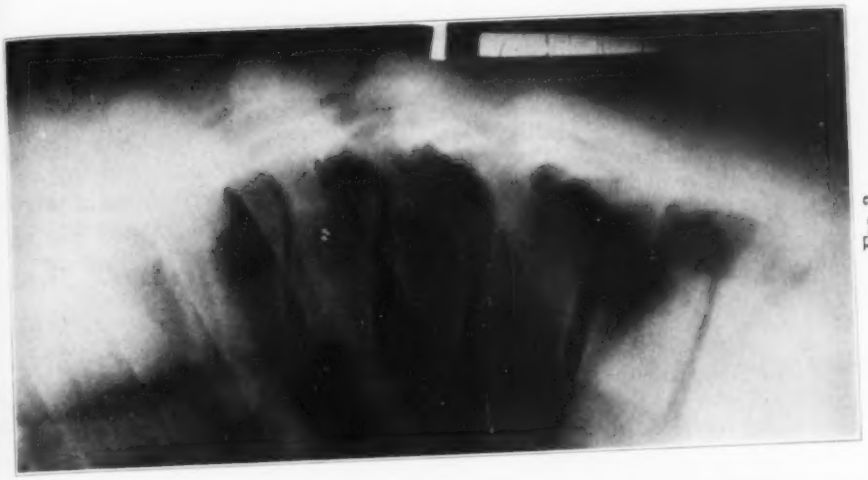

FIG. 3

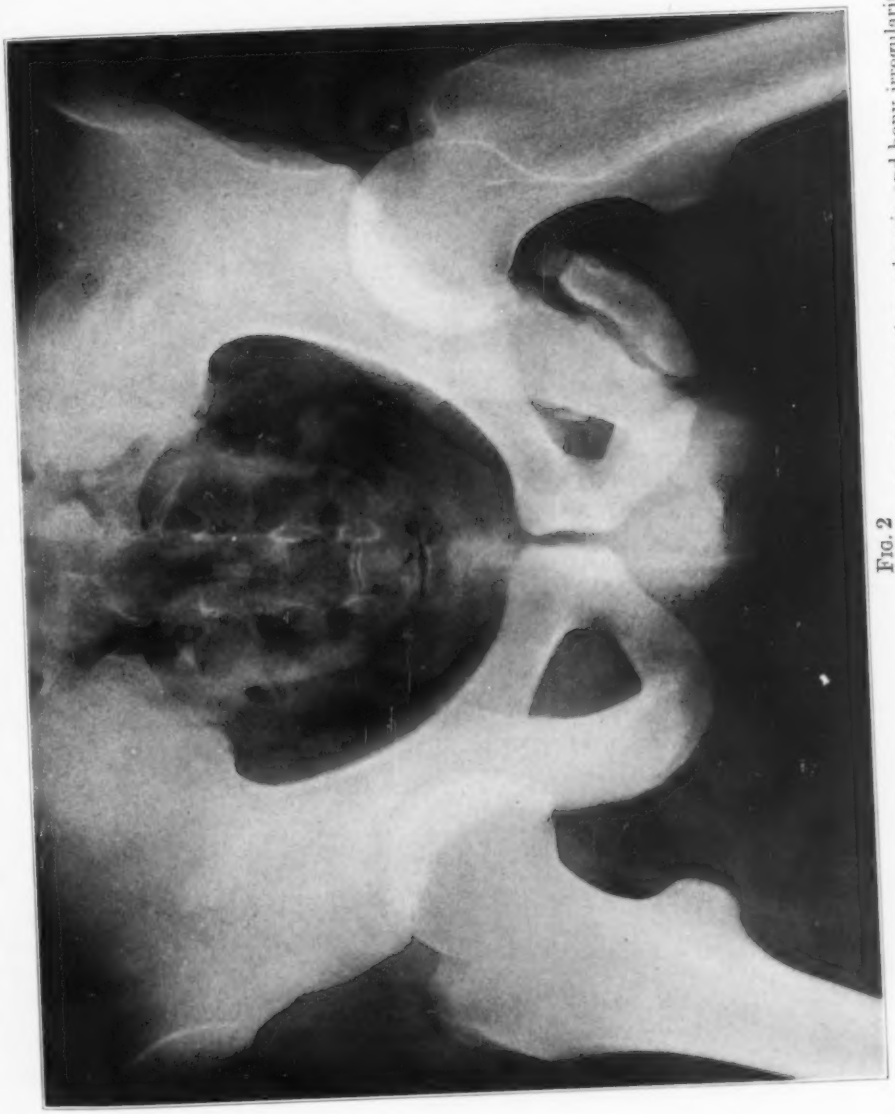

FIG. 2

Fig. 2: The secondary ossification center has failed to unite. Fragmentation, sclerosis, and bony irregularities are noted. No evidence of bony union can be determined.

Fig. 3: Lateral view of the thoracic spine, showing widespread wedging as a result of an old osteochondritis.

COMMENT

No explanation for the shortening of the right leg could be found, either in the history or in the physical examination. The painful thoracic spine was, in all probability, due to faulty mechanics, and not to any activity of the osteochondritic process. The ischial lesion was entirely asymptomatic, and was found purely by accident. The extensive changes in the thoracic spine, coupled with the failure of the ischial secondary center to fuse, would suggest the possibility of some systemic factor. Two basal metabolic readings of minus 24 and minus 25 may be significant in the etiology, although there were no outstanding symptoms or signs to substantiate a diagnosis of frank hypothyroidism, other than sparse hair distribution and a consistently slow pulse.

CONCLUSIONS

Failure of the secondary ossification center of the ischium to unite with the diaphysis is possibly a part of a general osteochondritic dysfunction. In the case presented, it was associated with a moderately severe, but healed, osteochondritis of the thoracic spine and a short femur of undetermined origin; there was a history of a short leg in the father.

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TRANSPLEURAL RUPTURE OF A TUBERCULOUS SPINAL ABSCESS TREATED SUCCESSFULLY BY STREPTOMYCIN *

Report of a Case

BY CHARLES MORGAN, M.D., AND DAVID M. BOSWORTH, M.D., NEW YORK, N. Y.

From the Orthopaedic Service, St. Luke's Hospital, New York City

The following case of tuberculosis of the spine with a large paraspinal abscess is reported because, in spite of rupture of the abscess into the lung and the resultant spread of lesion, the patient survived. The authors believe that recovery may be attributed to the administration of streptomycin.

CASE REPORT

A male physician, thirty-five years old, entered the Armed Services in June 1942. At that time tuberculin tests and roentgenograms of the chest were negative. He was in good health until June 1943, when, while stationed in Tunisia, he received a blow on the right chest. The patient experienced severe chest pain, malaise, and hemoptysis. After this he had two episodes of sudden, severe pleuritic pain, associated with hemoptysis of three or four days' duration. In September 1943 he returned to the United States; at that time a sputum examination was positive for tubercle bacilli, and the patient was admitted to Fitzsimmons General Hospital. He remained there under treatment until March 1944, when he was discharged from the Army.

* Presented at the meeting of the New York Academy of Medicine, New York City, October 1945.

At the time of his discharge the patient noted the insidious onset of neck stiffness, which was present particularly while he was seated for meals or shaving; it was relieved by moving his neck about. This condition gradually became worse, and the patient returned to Fitzsimmons General Hospital in June 1944.

One month later, fullness was noted in the neck, along the anterior border of the right sternocleidomastoideus. Roentgenograms of the spine at that time were reported as negative. A chest roentgenogram showed a paramediastinal shadow on the right. The symptoms of pain and stiffness increased and a torticollis appeared, with the head tilted to the left. Roentgenograms of the spine, taken in August, were still reported as negative. The surgical diagnosis was cervical lymphadenopathy. A biopsy was carried out, revealing a cervical paraverterbral abscess, and the incision was packed open. Following this the patient received 25,000 units of penicillin intramuscularly every three hours for two weeks, with no

FIG. 1-A

FIG. 1-B

Fig. 1-A: Shows tuberculosis of cervical spine, with abscess shadow anterior to vertebral bodies, extending from occiput downward into thoracic area.

Fig. 1-B: Shows shadow of bilateral abscess in upper thoracic region, with some narrowing of intervertebral spaces and sclerosis of vertebral bodies.

FIG. 1-C

Abscess can be seen in right ilium.

effect. The pain in the neck became so marked that he was placed in a jacket which included the head and neck. Roentgenograms now were interpreted as showing a tuberculous lesion of the cervical spine. The patient was transferred to St. Luke's Hospital.

FIG. 2-A

FIG. 2-B

Recent roentgenograms show solid fusion of spine from occiput to tenth thoracic vertebra, and healing of lesions of vertebral bodies, with beginning synostosis in the cervical region.

FIG. 2-C

Shows advanced healing of abscessed right ilium.

Admission examination at St. Luke's Hospital showed a chronically ill male, who had swelling of the right side of the neck and a draining sinus. There was marked spasm of the paraspinal muscles, with limited motion. Percussion and auscultation of the chest failed to indicate pathological changes.

Laboratory studies showed no acid-fast bacilli in the sputum or urine. Cultures of material taken from the cervical sinus yielded hemolytic *Staphylococcus aureus*; and, later, a positive guinea-pig test for tuberculosis was obtained. Mild anaemia and leukocytosis were present.

Roentgenograms of the entire spine (Figs. 1-A, 1-B, and 1-C) disclosed slight narrowing of the intervertebral discs from the second to the sixth cervical vertebrae, with areas of irregular sclerosis and bone destruction of the anterior borders in the same region. There was marked widening of the pre-

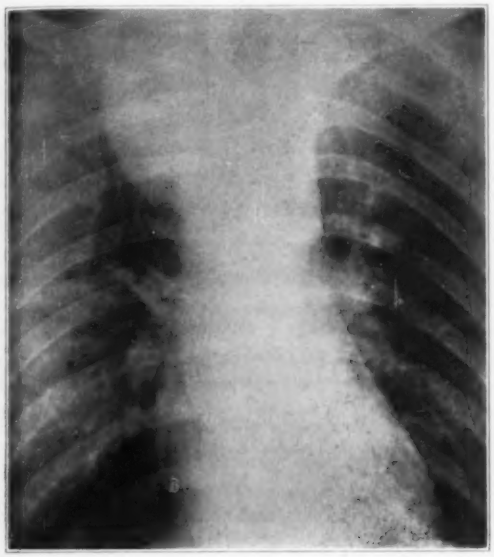

FIG. 3-A

FIG. 3-B

Fig. 3-A: Roentgenogram of the chest, before rupture of the abscess.

Fig. 3-B: Roentgenogram taken two days after rupture of the abscess. Shows generalized infiltration of both lungs and decrease in abscess shadow.

vertebral soft tissues, extending from the occiput down into the mediastinum on the right, as far as the level of the aortic arch. The first three thoracic vertebrae also showed small areas of bone destruction. Irregularity of the discs extended as far as the ninth thoracic vertebra. A small area with sclerotic changes, just lateral to the left sacro-iliac joint, was also noted. The chest roentgenogram showed a narrow zone of fibrotic scarring, which radiated laterally from the right hilum to the paraspinal abscess. No active infiltration was noted. Intravenous urography was negative.

In view of these findings, and after consultation with Leo Mayer, M.D., George G. Ornstein, M.D., and George F. Hoch, M.D., spinal fusion was advised. The patient was given penicillin and transfusions of whole blood.

On October 21, 1944, a fusion of the left hemispine, from the occiput to the first thoracic vertebra, was performed. On January 22, 1945, the left hemispine fusion was completed from the seventh cervical vertebra to the tenth thoracic vertebra. There was no postoperative reaction on either occasion. Between spinal operations, penicillin and transfusions were continued, as indicated. A small sinus developed, just inferior to the original one. Incision along the posterior margin of the right sternocleidomastoideus was done on

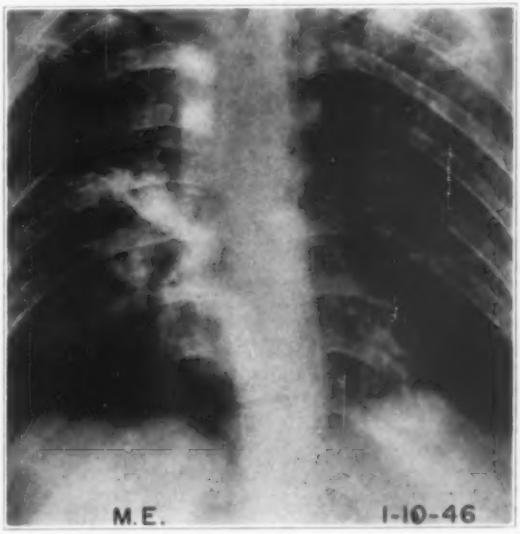

FIG. 3-C

Roentgenograms on January 10, 1946, show clearing of lung shadow and absence of abscess shadow.

TABLE I

PATIENT'S RESPONSE AFTER INSTITUTION OF STREPTOMYCIN THERAPY

Temperature		Sedimentation Rate		Leukocytosis		
Days	Degrees	Days	Millimeters per Hour	Days	White Blood Cells	Percentage of Polymorphonuclear Cells
–1*	101.0	0**	77	–4*	17,150	91
0**	100.6	12	58	10	12,100	82
1	100.6	25	47	12	9,800	82
2	102.4	33	40	26	6,000	77
3	101.2	40	37	33	5,000	73
5	100.6	53	33	53	6,500	62
7	99.2	62	24			
9	98.6	73	12			

* Days prior to administration of streptomycin.
** Day streptomycin was started.

December 26, 1944, in an attempt to divert the drainage away from the carotid sheath. Solid fusion occurred from the occiput to the tenth thoracic vertebra, inclusive (Figs. 2-A, 2-B, and 2-C).

Intramuscular penicillin was continued for nine and one-half months, without healing of the sinuses or regression of the mediastinal abscess. It was discontinued after 32,000,000 units had been injected. The sinuses were then irrigated with penicillin, but the intrathoracic abscess could not be reached by catheter or fluid, because of the obstruction offered by the subclavian vessels. In spite of this treatment and repeated transfusions, the poor general trend continued.

By September 1945, the patient was in an emaciated condition with marked leukocytosis, moderate anaemia, a markedly elevated sedimentation rate, and massive weight loss. On the evening of September 5, 1945, disaster occurred. The paramediastinal abscess ruptured through the pleura and lung into the bronchial tree. The lung was sprayed with the purulent discharge from the abscess.

The administration of streptomycin was started less than twenty-four hours after this episode. The patient received 4,000,000 units during the first twenty-four hours, and the dosage was then maintained at 1,000,000 units per day for fifty days,—a total of 54,000,000 units.

At the end of that time the patient showed marked improvement. His general condition had changed from a desperate state to one of recovery. The sinuses, which had been open for a period of thirteen months, closed in twenty-one days. The temperature went up after rupture of the abscess (Table I), but rapidly subsided to within normal limits, where it remained throughout the rest of the hospital stay. The sedimentation rate, which had been markedly elevated, fell steadily to within normal limits. The marked leukocytosis, present before rupture, reverted to normal with therapy. The sputum, which had been 0 on the Gaffky scale, became Gaffky V after rupture of the abscess. This, too, rapidly declined to 0 by the seventeenth day. All coughing and raising of sputum had stopped at this time. Serial roentgenograms of the chest reflected the dramatic change (Figs. 3-A, 3-B, and 3-C). A chest roentgenogram, which had been taken on August 8, 1945, showed the dense right paramediastinal abscess and slight scarring in the right upper lobe, but no active infiltration. A roentgenogram on September 7, 1945, two days after the rupture, showed a decrease in the density and size of the abscess, but parenchymal infiltration appeared in the right upper lobe and also in the left lower lobe. The progressive clearing of this infiltration and of the original lesion continued.

EPIPHYSEAL COXA VALGA

Report of Two Cases

BY ALVIS D. FINCH, M.D., AND WILLIAM M. ROBERTS, M.D., GASTONIA, NORTH CAROLINA

From the North Carolina Orthopaedic Hospital, Gastonia

Many articles on epiphyseal coxa vara or slipping of the capital femoral epiphysis in adolescence, with a residual varus deformity, have been published since the latter part of the nineteenth century[1]. Apparently, however, no case of epiphyseal coxa valga in the presence of a morphologically well-formed acetabulum has been reported in the English literature, although Müller in 1926 reported the development of coxa valga with epiphyseal slipping in cases of hypoplastic, flattened, or almost vertical acetabula. The condition is not mentioned in standard orthopaedic textbooks. A study of 100 cases of slipped capital femoral epiphyses, treated at the North Carolina Orthopaedic Hospital since 1921, has disclosed only two patients with a valgus deformity. This apparent rarity of epiphyseal coxa valga warrants the report of these cases.

CASE REPORTS

Case 1. A. F., a negro girl, aged fourteen years, was admitted to the North Carolina Orthopaedic Hospital on February 22, 1944, with chief complaints of stiffness, restricted motion, and pain in the hips. In the summer of 1940 her father had noticed that the patient limped on the left leg; there was no associated pain. In the fall of 1941 she began limping on the right leg, also. Gradually the disturbance in her gait increased, and, on February 23, 1943, the patient was admitted to Duke Hospital. A summary of the significant findings at Duke Hospital is as follows:

"Five months previous to admission, the patient began to limp on the left leg and complained of pain in the left hip. There was no history of trauma or of other known exciting factor. The pain was dull and aching in character, aggravated by motion and weight-bearing, and relieved by rest; it gradually became more severe. During the past month the patient has hardly been able to get around.

"*Physical Examination*: Temperature 37.4 degrees centigrade, pulse 82, respirations 20, blood pressure 110/70. The patient is a well-developed, well-nourished, large colored female who walks rather slowly, taking short steps, with the legs close together and in moderate external rotation, with a rolling motion of both hips, and a shuffling of both feet. The skin is warm, moist, and elastic, without lesions. The patient has the adult female distribution of hair. Both lower extremities are held in external rotation, and there is considerable limitation of internal rotation, abduction, and flexion. There is no tenderness over either hip to palpation or fist percussion. Except for these findings, the general physical examination is within normal limits.

"*Accessory Clinical Findings*: Hemoglobin 91 per cent., white blood cells 6,050, sedimentation rate (corrected) 10 millimeters per hour. Routine Kahn and Kline tests are negative. Urinalysis is negative. Roentgenographic examination of the pelvis, including both hips, shows the neck of the femur to form an angle with the shaft of 165 degrees, bilaterally. There is marked slipping of both femoral epiphyses.

"On February 27, 1943, the patient was given a general anaesthetic; the hips were readily hyperextended and the extremities were internally rotated about 45 degrees and placed in bilateral long-leg casts, with cross-bar struts which maintained the extremities in internal rotation and abduction of about 30 degrees. She remained in these casts until June 23, 1943. Roentgenograms made at that time revealed no change over her original roentgenograms."

Upon admission to the North Carolina Orthopaedic Hospital, on February 22, 1944, the patient was walking with crutches, but she experienced some difficulty because of restriction of motion in the hips. The right lower extremity was held in a position of about 15 degrees of external rotation, and the left lower extremity in 10 degrees of internal rotation. She was treated conservatively, with traction and bed rest. This, however, did not result in any improvement in the roentgenographic appearance of the hips; in fact, recent roentgenograms indicated the development of progressive degenerative changes. There was marked limitation of motion in the hips in all directions.

The preliminary roentgenogram (Fig. 1-A) of the patient's pelvis and hips, taken February 26, 1943, showed moderate, but marked, slipping of both capital femoral epiphyses; the head was displaced upward, laterally, and anteriorly. A line projected upon the upper margin of the femoral neck transected a third or more of the head of the femur. This was in marked contrast with the usual epiphyseal coxa

FIG. 1-A

Case 1. Roentgenogram taken February 26, 1943, shows slipping of both capital femoral epiphyses.

FIG. 1-B

Roentgenogram taken April 18, 1946.

FIG. 2-A

Case 2. Roentgenograms taken September 8, 1936, upon admission to the Hospital, show slipping of the heads of both femora.

FIG. 2-B

Eight months later, the epiphyses have almost closed.

vara, in which the head is displaced backward, downward, and medially, and such a line would transect little or none of the head of the femur[3]. Study of the roentgenogram indicated clearly that the coxa valga was not merely an expression of anteversion of the neck of the femur. Unfortunately, lateral views of the hips were not made.

CASE 2. M. H., a lanky negro girl, aged thirteen years, was admitted to the North Carolina Orthopaedic Hospital on September 8, 1936, with a history of pain of insidious onset in the right hip, which began seven weeks before. There was a rather sharp limp of the right hip, considerable spasm of the muscles of the hip and thigh, especially the adductors, and limitation of motion in abduction. The patient had had no trouble whatever with the left hip, in which there was no limitation of motion. The extremities were of equal length. Except for the findings about the right hip, the general physical examination was within normal limits.

A blood examination gave the following results: hemoglobin 84 per cent., red blood cells 4,370,000, white blood cells 8,250. The blood Wassermann was negative. A urinalysis was negative. Roentgenographic examination of the pelvis (Fig. 2-A) showed slipping of the heads of the femora upward, laterally, and anteriorly, although not to such an extent as in Case 1. Unfortunately, lateral roentgenograms of the hips were not taken.

This patient was treated by adhesive traction for a period of eight weeks, and then a right hip spica was applied for an additional six weeks. This resulted in complete relief of the pain and muscle spasm of the right hip, and in considerable improvement in abduction. When last examined, on June 20, 1939, about three years after onset of the first symptoms, the patient walked without any limp and had had no pain for two years. There was no limitation of motion in either hip joint, except for the last few degrees of abduction. The final roentgenograms (Fig. 2-B), taken on May 11, 1937, showed almost complete closure of the capital femoral epiphyses in satisfactory positions, with no evidence of any degenerative changes.

The practical significance of recognition of epiphyseal coxa valga lies in the fact that the use of the conventional, or Whitman, type of reduction by forcible internal rotation is contra-indicated, as it probably increases the displacement of the head of the femur and favors the development of avascular necrosis, as in Case 1.

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UNUSUAL REGENERATION OF BONE IN A CHILD

BY DONALD J. MAGILLIGAN, M.D., BROOKLYN, NEW YORK

There is nothing new about the fact that missing bone fragments can be replaced by spontaneous regeneration. However, the author feels that some of the features of this case make it sufficiently unique to be worth presenting.

The patient, a six-year-old girl of Puerto Rican origin, was brought into Greenpoint Hospital on July 12, 1945. The only history obtainable was that she had been struck by an automobile truck just prior to admission. Her general condition, together with the language difficulty, precluded any other questioning.

FIG. 1

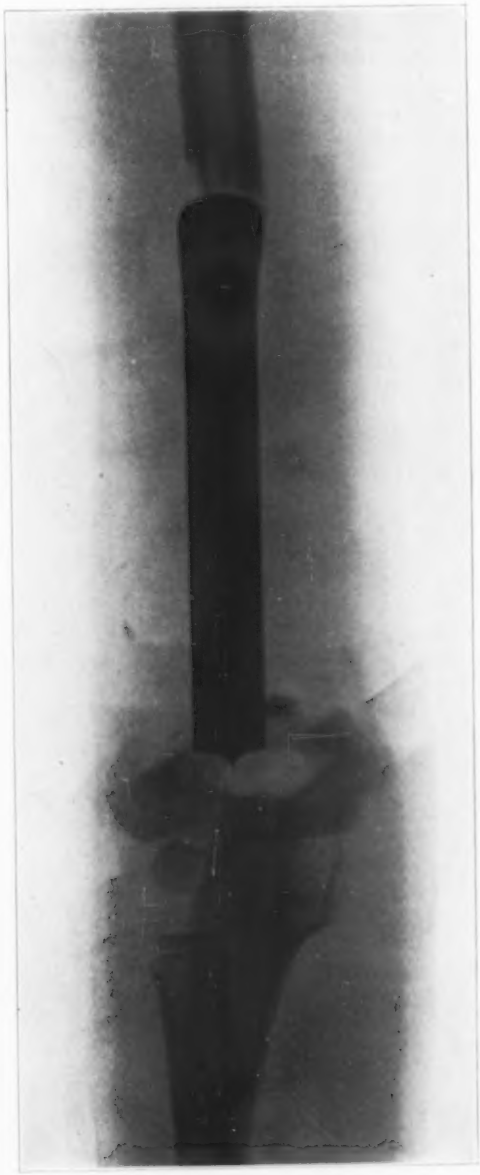

FIG. 2

Fig. 1: Roentgenograms taken immediately after admission to the Hospital.
Fig. 2: The Smith-Petersen nail is demonstrated *in situ*.

Physical examination revealed that the child was conscious, but she did not respond to questions. The only pertinent positive physical findings were confined to the right upper extremity. There were two parallel lacerations, about an inch apart, and each about an inch in length, over the posterior aspect of the humeral condyles. There was markedly excessive mobility of the lower portion of the arm, and moderate bleeding from the lacerations. The forearm showed no external evidence of injury. Finger and wrist motions were normal, and there was no evidence of circulatory disturbance. Sensation was not tested, but there seemed to be no impairment of motor power.

Roentgenograms revealed a comminuted fracture involving both humeral condyles, with one small fragment, apparently free, adjacent to the condyles. The section of the humeral shaft extending from its mid-portion down to the condyles was completely absent; the bones of the forearm were intact (Fig. 1).

Plasma was administered, followed by a mild reaction, with some shock, and the patient passed some blood-tinged urine. Immediate consultation with surgeons and urologist was held, and the consensus was that there were no complicating factors which contra-indicated operation.

It was at first felt that the best way to meet the situation would be to insert a fibular graft into the space left between the fragments. The reasons for this decision were, first, because it was quite obvious that some measures must be taken to maintain the length of the extremity and at the same time to allow a reasonable chance of preventing angulation or torsion deformity; and, second, because it was felt that the fibula presented the most readily accessible source of graft material. The fact was taken into consideration that wounds compounded from within, when treated early and adequately, in general stand a sufficiently favorable chance of healing without infection to justify this apparently radical procedure.

The patient was allowed to recover from shock, but her condition three hours after admission was

FIG. 3

Approximately three months after operation. There is abundant bone formation, and a pseudarthrosis appears to be forming around the proximal end of the nail.

such as to make it seem unwise to do more surgery than was absolutely necessary; the original plan to take a graft from the fibula was therefore abandoned. The two lacerated wounds were debrided, and were found to communicate with an irregular tear in the lower lateral portion of the triceps and its tendon. Exploration through this tear revealed a perfectly smooth tunnel, leading from the condyles up to the lower end of the proximal fragment. The wall of this tunnel seemed to be intact. As nearly as could be determined by the examining finger, there was absolutely no other soft-tissue injury present.

In the lower part of the tunnel was a small, loose fragment of bone, apparently derived from the condyles (Fig. 1). It was then felt even more strongly that something must be done to keep the walls of the tunnel from collapsing, and to maintain its length, so that later bone-grafting could be done. Several suggestions were made, none of which seemed feasible or wise. Finally, after the idea of using such things as clamps, tissue forceps, or syringe plungers had been discarded, it was suggested that a Smith-Petersen hip nail might serve the purpose. After the previously mentioned loose bone fragment had been removed, a three-and-one-quarter-inch nail was sterilized, and was inserted through the original laceration into the tunnel. The soft tissues were approximated in layers, and the skin lacerations were closed tightly with black silk sutures. The patient was returned to the ward, and the extremity was immediately placed in traction.

Her immediate postoperative course was singularly uneventful, there being only very slight

FIG. 4

There is now solid bone formation. The apparent pseudarthrosis has disappeared.

temperature elevation. The forearm, hand, and fingers showed no manifestation of circulatory, nerve, or muscle involvement. It was decided that on July 23 (the eleventh day) the Smith-Petersen nail would be removed, and a bone graft from the leg be inserted. Unfortunately, on the day of operation, a very small quantity of purulent fluid was found in the original wound, and it was thought best to cancel the procedure. A spica cast was applied under anaesthesia, with the elbow at a right angle and the forearm supinated. One roentgenogram, taken nineteen days after the trauma had occurred, showed that a considerable amount of new bone had already been formed; and the idea of removing the nail and substituting a bone graft was then deemed to be impractical and unnecessary. On September 10, the cast was removed, and a posterior molded splint was applied. One week later, the splint was removed, the extremity was placed in a sling, and active motion was started. The patient was kept in the Hospital under observation until November 3, roentgenographic studies being made at intervals.

Since leaving the Hospital, she has been seen only once in the Out-Patient Department, on December 10. Roentgenograms taken on that date (Fig. 4) showed anterior angulation of the distal portion of the humerus. The clinical findings were as follows: The original lacerations had completely healed and were non-adherent. There was a crepitant sensation, just deep to these wounds. There was no deformity. By actual measurement the right arm was one-quarter of an inch shorter than the left. There was no definite atrophy of the arm or forearm. Motion of the right shoulder was complete and painless. Motion of the right elbow ranged from 80 degrees of flexion to 150 degrees in extension; pronation and supination were complete and painless. Motion of the wrist and fingers was complete and painless. There was neither sensory nor motor-nerve disturbance of the extremity, nor was there any alteration in the circulation.

Although the angulation shown in Figure 4 unquestionably had some bearing on the range of motion, it was not otherwise apparent clinically. On palpation, the bony landmarks were in normal relationship to each other, and the carrying angle was normal. Up to that time, there had been no apparent growth disturbance at the lower end of the humerus. Unfortunately, the patient has been lost sight of and cannot be traced; hence it cannot be stated whether or not there has been any subsequent change.

COMMENT

It would appear from this case, in which there was an intact periosteal tunnel and spontaneous regeneration of a segment of humerus, three and one-quarter inches in length, that bone can regenerate from periosteum alone,—at least in children. There was no evidence at any time of irritative or inflammatory reaction at the site of the nail, and the rapid regeneration of the bone bears witness to the fact that vitallium does not inhibit such regeneration.

MARCH FOOT IN A SEVEN-YEAR-OLD CHILD

BY HAROLD M. CHILDRESS, M.D., JAMESTOWN, NEW YORK

The incidence of march fracture of a metatarsal bone, or march foot, was greatly increased during World War II. Civilians as well as military personnel were affected. The occurrence of such a bone lesion in a small child, however, is extremely rare. Only one such instance has been found, after a fairly extensive review of the medical literature. This case, that of a ten-year-old girl, was mentioned by Zeitlin and Odessky[1].

CASE REPORT

R. L. W., a boy, seven years of age (Hospital Register No. 3442), noticed pain on the dorsum of the left foot about one month before admission to the hospital. There was no history of trauma, except that the patient had been walking on a concrete sidewalk one-half mile, three times daily. Discomfort in the foot appeared soon after this activity was started. Two weeks after the onset of pain, a rounded swelling was noted on the dorsum of the foot, which was extremely painful to pressure. The skin over this mass became slightly reddened and was hot to the touch. Rest gave complete relief. The patient remained ambulatory, but the pain became increasingly severe. The condition had been diagnosed by the family physician as an acute infection of the soft tissues.

Physical examination at the time of admission to the hospital disclosed a small, hard, rounded mass over the mid-portion of the second left metatarsal bone. At this time there were no signs of inflammation. Tenderness to localized pressure was moderate. The foot musculature and the posture were good. All the other bones and joints were normal.

A urine examination was negative. The blood examination was as follows:

Red blood cells	4,450,000
Hemoglobin	85 per cent.
White blood cells	7,800
Polymorphonuclear neutrophils	47 per cent.
Lymphocytes	50 per cent.
Monocytes	3 per cent.

FIG. 1

Roentgenogram, taken one month after onset of pain, shows typical march fracture in the healing stage.

The roentgenograms (Fig. 1) were interpreted as showing a fusiform area of proliferative periosteal bone, centered about the mid-shaft of the second left metatarsal bone. A thin fracture line was seen in the center of this fusiform mass. The appearance was that of a march fracture or an insufficiency fracture.

The patient was confined to bed for ten days, and then was allowed partial activity for the next three weeks. A low combination longitudinal and metatarsal arch support of sponge rubber was placed in the left shoe. When this patient was last seen, three months after onset, the mass had decreased in size; the pressure tenderness had disappeared; and he was able to walk normally without discomfort.

Had this patient been examined during the acute stage, a diagnosis might have been made of osteomyelitis or even of osteogenic sarcoma. March fracture always should be considered in osteoblastic lesions of the metatarsal bones, even in young children.

1. ZEITLIN, A. A., AND ODESSKY, I. N.: "Pied Forcé" or "Deutschländer's Disease". Radiology, **25**: 215–222, 1935.

Education Section

FUTURE DEVELOPMENT OF POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY*

BY RALPH K. GHORMLEY, M.D., ROCHESTER, MINNESOTA

The Joint Committee on Postgraduate Training in Orthopaedic Surgery asked your Program Committee for time to present some of the problems that are before us, in the hope that a frank discussion might be provoked. We feel that The American Orthopaedic Association should be, and is, more interested in these problems than any other group. We hope that some suggestions may come from you which will help us to make further plans for the training of orthopaedic surgeons in this country.

In the past year we have tried to keep you informed of some of our activities. An account of the present status of the work of the Committee and of what is left for immediate accomplishment will be presented by the Secretary, Dr. Shands.

How well we are going to train persons seeking to be orthopaedic surgeons is a question that should be given considerable thought by every member of this Association.

PROBLEMS IN DEVELOPMENT OF A TEACHING PROGRAM

A carefully planned, but rapid, increase in the number of resident training programs throughout the country has been made. How well some of these will stand the test of time and experience remains to be seen. Training programs will have to be evaluated carefully and, unfortunately, some may have to be abandoned. Already we find, much to our regret, that some of the residencies, approved after much discussion and correspondence, are not functioning. Such disappointments are bound to come. The Committee has tried to direct the development of residencies in places where it seemed that sufficient material and personnel existed to justify a training program. The stumbling blocks in some places seem to be as follows: (1) administrative difficulties, in particular, where the personnel of two or more hospitals have to work together; (2) the regrettable, but apparently universal, inability of human beings to avoid friction; and (3) the fact that the main interests of many orthopaedic surgeons are in directions other than graduate medical training.

The difficulties of administration usually can be worked out satisfactorily by administrative officials who are interested in developing a program of graduate training. These problems vary greatly from place to place and no one solution can be found for all. The second and third problems are those of individuals, and can be solved only if the development of orthopaedic surgery becomes of such absorbing interest that characteristics which lie at the bottom of imperfect human nature are surmounted. In most instances, however, the development of a well-run residency and the training of a group of able orthopaedic surgeons will do much to enhance the reputation of the chief of service in his community, and will bring to him a lasting feeling of satisfaction.

PROBLEMS OF REVIEW OF, AND TRAINING IN, THE BASIC MEDICAL SCIENCES

The recent emphasis on furnishing an opportunity for residents to review and to advance their knowledge of the basic medical sciences has been the source of some discussion and confusion, and may have held up development of the program in some communities. It is not my purpose to present this problem in detail, but it must be pointed out that, in general, the need for this phase of training has been widely recognized, and today many types of special training in the basic sciences are included in programs for training residents. What method of presentation of these subjects will prove to be best remains to be seen, but out of the many plans should come some improved methods.

Orthopaedic surgeons, like physicians in all other specialties, have come to realize that they cannot develop their specialty to the exclusion of all else, and that it is necessary that they keep informed of the many fundamental developments in general medicine and surgery. Therefore, the program must be directed toward a better and broader training of the specialist.

The day may not be far distant when a uniform examination in the basic sciences must be passed by a candidate before he can begin training in a specialty. To me it seems that it would be a mistake to institute such a procedure, but it is a plan seriously contemplated by the specialty boards at this time.

* Read before the meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 28, 1946.

PROBLEMS OF TRAINING IN ORTHOPAEDIC SURGERY

Dr. Frank Dickson, in his Presidential Address before this Association in 1940, said: "There is a responsibility which rests upon the members of the American Orthopaedic Association that I doubt has been appreciated in its true importance. I refer to the obligation which rests upon each of us to provide satisfactory training to the extent of his ability for those who wish to enter the field of orthopaedic surgery. . . . There must be, in addition, a willingness to coordinate these one-year and two-year training opportunities with others, so that an acceptable three-year period of training may be available for every applicant for Board certification who is deserving of such training. It is possible that you may be called upon in the near future to cooperate with the American Board to this end."

Because of the recognized scope of orthopaedic surgery, training in this specialty must cover three phases. This is recognized by all, and no further emphasis is necessary. To cover all three phases of the training in one institution is oftentimes impossible. The development of separate hospitals for the care of crippled children has been a notable trend in the past quarter of a century. It seems possible now that this separation may have been overemphasized. However, the principal problem in this phase is to utilize to the utmost, in the training of orthopaedic surgeons, the existing services for treatment of crippled children. Three questions must be answered concerning this problem:

1. Is there enough orthopaedic surgery among children to allow adequate training in this department of the specialty for those who ask for qualification therein?

2. Is one year of training in orthopaedic surgery, as applied to children, sufficient to qualify a man to do this work?

3. Will economic and political trends further reduce the amount of orthopaedic surgery among children which is now available in institutions approved for residency?

Because of the relative scarcity of orthopaedic services on which the patients are children, the Committee urges that all such services which are available be used for training purposes when it is possible to do so.

Many problems relating to the adult phase of orthopaedic surgery remain to be solved. The scope is large and, while orthopaedic surgeons cannot take care of every patient whose complaints might come under this heading, it is their responsibility to point the way toward newer and better methods of diagnosis and treatment of orthopaedic conditions and to assume leadership in the teaching of these methods.

To anyone who has watched the trends during the past quarter of a century, the shift of responsibility for the care of fractures and of teaching concerning this care from the general surgeon to the orthopaedic surgeon is obvious. This is no doubt due to the fact that the orthopaedic surgeon has shown more interest and ability to carry out this task. Many patients have come to regard the orthopaedic surgeon as the specialist to be consulted in the care of difficult fractures. Most of the service men from World War II who were cared for in General Hospitals learned to regard the orthopaedic surgeon as the man who cared for injuries of the extremities, as well as amputations and most aches and pains in the extremities.

Certain professors of surgery are loath to permit orthopaedic surgeons to assume the care of fractures or the instruction of students concerning fractures. They explain their attitude by pointing out that it is their responsibility to train general surgeons and that, of course, part of the training must be in the care of fractures. This attitude is not justified in institutions where orthopaedic surgeons are well versed in the care of fractures, and anxious to help with that phase of teaching. Continued effort on the part of all orthopaedic surgeons to demonstrate ability in the care of fractures and to improve methods of teaching will result in more services coming under the care of orthopaedic surgeons.

COMMENT

Are we to continue to supply and to supervise the training of men to carry practice in the specialty to better and higher levels of accomplishment? Now is the time to realize the position of orthopaedic surgery. It has developed rapidly and has made great strides. With the help of the young men who are becoming orthopaedic surgeons, the specialty should go forward to greater and better things.

A number of affiliations between training services have been developed. The Committee has not felt that it should designate services for affiliation, although suggestions have been made in some instances. We feel that more lasting affiliations will be made through mutual selection by chiefs of services. If, in any instance, the Committee can help in the selection of affiliates, it will be glad to do so.

It is not, and never has been, our purpose to attempt standardization of teaching services. Some minimum requirements have been established and will be a guide to many. As time goes by and experience is gained, a greater tendency to standardization may develop, particularly if some services seem to develop a consistently better type of orthopaedic surgeon than others. The following factors seem to be important in a good teaching service: (1) willingness of orthopaedic surgeons to devote time

to teaching, (2) ability of such personnel to teach, (3) amount and variety of clinical material, both in the hospital and in out-patient departments, (4) availability of laboratories, postmortem service, pathological demonstrations, library and motion-picture films, (5) the possibility of conferences and seminars, (6) contacts with men on other services, both teachers and students, with exchange of ideas about current medical topics, and (7) frequency of contact with visiting surgeons and lecturers.

In order to present examples of some of the organized teaching services for training orthopaedic surgeons, I have asked that several of the plans for training be submitted. These plans are diversified and often complex.

To those who have visited the British Isles, the position of British orthopaedic surgeons in the scheme of specialization has seemed more advanced and secure than our own. They have been recognized more widely than American orthopaedic surgeons have been. During World War I, due to the magnificent leadership of Sir Robert Jones, the specialty became well founded and well recognized and, in turn, it has contributed much to the advancement of medical science.

One of the distinguished leaders of British orthopaedic surgery, Mr. Harry Platt, is a guest at this Meeting. That his group is contributing to the development of this specialty is manifested by two articles written by him, which have appeared in British medical literature in the past two years. These deal with "Orthopaedic Surgery and the Future" and "The Place of Orthopaedics in Medical Education". Both of these articles are worth perusal and study.

Our Committee looks upon the development of a postgraduate training program as a never-ending task. The ultimate goal—a group of perfect orthopaedic surgeons—will, of course, never be reached. One of the most fascinating features of the practice of medicine is the constantly changing viewpoint. New methods are devised, only to be superseded and outmoded by newer methods. Orthopaedic surgery is among the advancing phases of medical science and, if its practitioners are alert, its progress cannot be stopped. We want every member of this Association to feel it his duty to help develop better training for orthopaedic surgeons.

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DISCUSSION

Dr. Guy A. Caldwell, New Orleans, Louisiana: The report of Dr. Ghormley, covering the excellent contribution made by his Committee to meet a veritable crisis in the progress of orthopaedic surgery, is excellent and requires only commendation, rather than comment. The Joint Committee on Postgraduate Training has worked closely with the Council on Medical Education and Hospitals and with the Committee on Resident Training from The American Board of Orthopaedic Surgery.

Additional residencies for training in orthopaedic surgery must be made to conform with requirements of the Council on Medical Education and Hospitals of the American Medical Association, because the Council is the only organization which has authority to approve resident training programs in hospitals. Many hospitals seeking to have orthopaedic services approved for resident training are required to submit a formal application to the Council. The Council then sends a representative to the hospital to make a detailed survey, the report of which is submitted to the Council and to the Board's Committee on Resident Training. The latter Committee can review the report and make recommendations, but final approval of any training service rests with the Council on Medical Education.

The American Board of Orthopaedic Surgery was incorporated in 1934 and received official approval by the Advisory Board of Medical Specialties and the Council on Medical Education and Hospitals. Its stated purposes, as set forth in its charter, are, first, "to elevate the standard of qualifications for the practice of orthopaedic surgery and to certify those surgeons who voluntarily comply with its requirements" and, second, under Article 2, Section 2, "to test and determine the qualifications of applicants for examination and to issue certificates to those found qualified".

The Board is composed of nine members, elected by three component organizations,—namely, the Orthopaedic Section of the American Medical Association, The American Orthopaedic Association, and The American Academy of Orthopaedic Surgeons. The American Orthopaedic Association is represented by three members on the Board,—namely, Dr. LeRoy C. Abbott, Dr. Fremont A. Chandler, and Dr. Allen F. Voshell. Members are elected for a term of three years and no one member may succeed himself for more than three terms, or a total of nine years. It is evident from these facts that the nine Board members, representing the three component organizations, are obligated to carry out the stated purposes in conformance with the terms of its charter and the rulings of the Council on Medical Education.

In 1934, the Board set about its task by having those who then were practising orthopaedic surgery

submit their qualifications and references for review by a Committee on Eligibility. No standards of training having previously been established, this Committee necessarily used great latitude and discretion in review of the data submitted. The training and experience of most of the applicants were "irregular", as judged by present standards, but whenever an applicant was found to have acquired adequate experience in the specialty *by any means whatever* and was found to be limiting his practice to orthopaedic surgery, it was ruled that he was eligible for examination. Examinations were given with consideration and discretion, those of the earlier groups who passed the examinations were certified, and thus the work was begun.

However, to meet the obligation of raising the standards of orthopaedic surgery, the Board made certain rulings and announced certain intentions. It stated that thereafter an applicant must show that he had had *three years of intensive training in orthopaedic surgery,* at least *two* of which had been spent as resident on an orthopaedic service in an accredited hospital. Furthermore, it was announced in the rulings that, after 1938, three full years of resident training would be required. Therefore, an adequate interval of time from 1935 to 1938 was allowed to enable all who were practising orthopaedic surgery, but who had received irregular training, to make application and take the examinations. At the same time hospitals, trainees, and diplomates interested in advising their assistants were notified that, after 1938, three years of training on orthopaedic services accredited by the Council on Medical Education and Hospitals would be required.

Early in its career, the Board's experience with applicants indicated that *in general,* training acquired by preceptorship or apprenticeship was inferior to resident training on accredited services. Such training was, therefore, discouraged and penalized in the interest of raised standards. The following ruling was made: "Preceptorship: In certain instances the Board may recognize training under the preceptorship system. Applicants under this category must show evidence of having received a rotating internship and at least one year of surgical training in an approved hospital, must have served for a period of at least five years as a full-time assistant to an orthopaedic surgeon certified by the Board and, in addition, must have been engaged in practice limited to orthopaedic surgery for a further period of five years. During this latter period he should have held a position on the staff of an approved hospital as orthopaedic surgeon and should have given evidence of scientific and professional ability."

From 1936 until 1944, there were only the two approved plans for training: (1) three years of orthopaedic resident training on services approved by the Council on Medical Education and Hospitals, and (2) the preceptorship plan, requiring the lapse of at least twelve years after graduation from medical school.

In 1944, after much consideration, the Board approved a third plan of training, designated as "Combined Assistantship and Resident Training". This was done because Board members recognized that, in certain cities where medical schools and approved resident-training services do not exist, diplomates have organized large private clinics and services in community hospitals which offer excellent opportunities for training for limited periods of time and have the advantage of placing the trainee in contact with private patients. Nevertheless, it was recognized from the outset that the number of such positions would be limited and that such services must be carefully reviewed by the Board itself, since the Council on Medical Education could not take cognizance of such services. On the whole, the plan is regarded by the Board as experimental and may prove to be impractical. Nevertheless, it is presently acceptable when it conforms to the following ruling: "In special instances with the approval of the Committee on Resident Training the Board will recognize for not over two years' training in orthopaedic surgery periods of training in which the candidate combines work in a hospital service with part-time assistantship to an orthopaedic surgeon certified by The American Board of Orthopaedic Surgery, provided that the major part of his time is spent by the candidate in the hospital service". Please note that credit for such service cannot be extended except when the applicant and the diplomate concerned submit *beforehand* to the Committee on Resident Training a prospectus, showing the plan of service and the amount and variety of clinical material available to the trainee in the course of his service.

With the outbreak of World War II and the mobilization of hundreds of orthopaedic surgeons and trainees into the Armed Forces, the question was raised as to credits that might be allowed for experience gained while in the Service. The Board, therefore, ruled as follows: "During the recent national emergency, credits up to a maximum of two years may be allowed for experience gained in surgery and orthopaedics while serving with the Armed Forces. Credits will be given only upon presentation of evidence that such service has, in the opinion of the Committee on Eligibility, been equivalent to similar periods of approved hospital training. Record of all such military service should be kept in the Record of Professional Assignments prescribed by the Advisory Board for Medical Specialties and submitted with his application.

"(a) A year of orthopaedic experience with the Armed Forces may be accepted to replace one of the three required years of orthopaedic resident training."

In general, the Committee on Eligibility approves such credit only when the Record of Professional Assignments shows that the trainee served for as much as a year upon an orthopaedic service in a General

Hospital under supervision of a diplomate of the Board. Because the work on such services was largely limited to fractures and other orthopaedic problems common to young adult males, the year of credit must apply to the required six months of fracture training and six months on the required year of adult orthopaedic surgery.

"(b) A second year of orthopaedic service with the Armed Forces may be credited as a year toward the practice requirement." This credit on the practice requirement is, in general, allowed to all applicants who served with the Armed Forces, regardless of the character of their service.

Although it obviously was essential that the Board recognize the problem of the trainees whose resident training was interrupted by the necessity for entering Military Service, and grant such credits as might be possible, it was equally important not to lower the standards of orthopaedic surgery. To have lowered these standards would be unfair to diplomates who had gone before and equally unfair to those who would come after the War. Nevertheless, the problem of evaluating orthopaedic training received while with the Armed Forces, and of advising the hundreds of young men whose training had been interrupted as to the character of service needed to complete their training, has greatly complicated the duties of the Secretary of the Board, the Committee on Eligibility, and the Secretary of the Joint Committee on Postgraduate Training.

In 1942, the Board divided the examination into two parts: The minimum requirements for Part I of the examination "shall consist of completion of a rotating internship followed by at least one year of resident training in orthopaedic surgery on an approved service".

For Part II: "Candidates applying for examination, Part II, must have successfully passed Part I and must have completed the prescribed training and practice periods, as defined in Article 7, Section 2".

The purposes for making this change were:

1. To screen prospective candidates for Part II early in their training, before they had invested five years' time and much money in the required training and practice periods;

2. To bring trainees in contact with the Board and its rulings early in their training, so as to guide them in selecting services for completion of their training;

3. To enable trainees whose training was interrupted by Military Service to complete their examinations in the Basic Sciences and Surgical Principles before they were too long separated from their medical school and hospital training;

4. To assist military authorities in the selection of men for orthopaedic services.

The plan was put into effect in 1943. It is a definite departure from the examination procedures used by other specialty boards; it adds greatly to the work of the Board, its officers and committees; and it multiplies the expense. Nevertheless, after three years of experience with the plan, the Board Members are unanimous in their approval. The plan has not only accomplished the four purposes mentioned, but, because Part I of the examinations has been given each year in four different centers with the assistance of many of our teachers and diplomates who would otherwise not be concerned with Board activities, it has awakened deep interest in, and support for, the work of the Board throughout the country.

From the time the Board was incorporated, it was recognized that well-rounded training in orthopaedic surgery should include instruction in the basic sciences (anatomy, pathology, physiology, and biochemistry) and in the three phases of orthopaedic surgery,—namely, those concerned with children, adults, and fractures. As time went on, it became apparent that many applicants were receiving poorly balanced training, either because the material in some of the approved three-year training centers was inadequate in some of the phases, or because the applicants took part of their work in one institution and part in another and skipped some of the essentials to well-rounded training, although they had spent the required three years on approved resident training services. In 1943, this problem was discussed with representatives of the Council on Medical Education and with their counsel; the total three-year program was defined to include one year of children's orthopaedics, one year of adult orthopaedics, six months of fractures, and six months of basic-science training. As stated in the ruling: "All of this work may be carried on concurrently" [in a hospital with an approved three-year training program]. "In many instances, however, the applicant may take each phase of this training in a different institution."

By defining the four phases of orthopaedic training thus, many of the three-year training services have improved and balanced their work, and many institutions have been able to set up approved training in one or more phases, thus making it possible to affiliate groups of special hospital services or to provide opportunities for matched training in different institutions, that will meet the requirements. During the present crisis, when it has been necessary for the Joint Committee on Postgraduate Training to expand the number of approved services rapidly, this foresighted ruling passed by the Board and Council in 1943 has been of great assistance.

During the years 1943, 1944, and 1945, the officers of all the Surgical Specialty Boards met repeatedly to confer upon measures to improve resident training. There was unanimous recognition of two weak points in all the Surgical Specialty programs: (1) failure in all but the better university-controlled programs to provide adequate instruction in the basic sciences, as related to the various specialties, and

(2) a tendency to permit trainees to launch out into specialty training without first being well grounded in surgical principles.

When the Boards, acting through the Council on Medical Education and Hospitals, began to request the hospitals and medical schools to allow more time for instruction in the basic sciences and more assistance in teaching, they received numerous inquiries and requests from medical schools and hospitals to specify approximately the period of time that should be given to such instruction and to specify a general pattern for such training. In an effort to comply with these requests, our Board defined its basic-science requirement and specified a general pattern for its teaching. This is not intended to be an absolute and fixed schedule,—especially not in the three-year training centers in which the basic-science training may better be integrated throughout the entire period. However, it has been and will be a real help to those who must try to obtain a complete, well-rounded training by matching the services of several institutions. Those associated with university-controlled programs, who are prone to criticize this and some similar rulings of the Board as being too specific and formalized, must be reminded that probably less than half of the candidates applying for examination and certification by the Board are trained in three-year centers.

In these few minutes I have tried to cover briefly the major steps in the evolution of the Board as it has struggled during the changing times to carry out the purposes for which it was created,—namely, "to raise the qualifications and standards for the practice of orthopaedic surgery and to certify those surgeons who voluntarily comply with its requirements".

During my term of office as Secretary, many complaints have been registered against the rulings of the Board and their interpretation by the various committees. In some instances, these have been justified and have been corrected as promptly as possible. Most complaints, however, have arisen from lack of familiarity with the rulings,—both by candidates and by our own diplomates. The saddest instances of candidates rejected for lack of proper training have arisen because they were ill-advised in the planning of their training by diplomates of the Board, who seem to think it unnecessary to familiarize themselves with the revised rulings issued from time to time. Their advice to candidates of today has been based upon their experience with the Board when they were examined, ten years ago. Others have been advised on the basis of the diplomates' conception of what should constitute good training, rather than on present rulings of the Council on Medical Education and the Board. The next most frequent criticism has been that the Board is *too rigid* and literal in the application of its rulings; but, curiously enough, there is another considerable group who complain that the regulations and requirements are enforced with too great leniency. The latter group would use a standard measuring rod and give an unqualified "yes" or "no". The former would eliminate all prescribed training, do away with the Committee on Eligibility, and invite all who claim to have had training to take the examinations, thus relying entirely upon a single examination to determine the standards of orthopaedic surgery in America.

In conclusion, I would like to urge the following points:

1. Let every diplomate of the Board review carefully the revised rulings.

2. Let us suggest to every prospective candidate, who wishes advice concerning his training, to write to the Office of Orthopaedic Information or to the Secretary of the Board.

3. Let us realize that better orthopaedic surgeons will be developed when the standards of resident training are maintained at a high level. This can best be accomplished through the efforts of this Joint Committee to keep in close touch with all training services. This Committee, therefore, must have the wholehearted support of every member of the Association.

4. Whenever and wherever you hear a diplomate of the Board criticizing its policies and rulings, please make note of his name and nominate him for membership on the Board. Three years of struggling with its problems will cure the complaints of its severest critics!

REPORT FROM THE COMMITTEE ON POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY AND THE OFFICE OF ORTHOPAEDIC INFORMATION

Since the last report of the Committee on Postgraduate Training and Office of Orthopaedic Information in the July issue of *The Journal*, the work of this Committee and Office has continued to be most active. As of August 15, there were on file 294 names of medical veterans who were desirous of obtaining orthopaedic training in 1946. However, because much of the information on these veterans was several months old, it was believed that many of this number have now either changed their plans for training or have received appointments, and that this Office was not notified. A questionnaire was sent out on August 17 to determine the present status of this group. As of September 6, 213 replies have been received. The analysis of the information on the questionnaires returned shows that the situation for orthopaedic training in 1946 is not so acute as it was several months ago. Of the 213 men who replied, ninety-nine, or 46 per cent., are still desirous of orthopaedic appointments for 1946; forty, or 18

per cent., for 1947; twenty-three, or 11 per cent., for 1948. Twenty-five, or 11 per cent., now have appointments, but will require further training to complete the requirements of the Board; and twenty-six, or 12 per cent., are either completing their training at the present time or have gone into general practice. It is likely that most of the eighty-one whose questionnaires have not been returned are also in this latter group.

The questionnaires indicate that the majority of those not placed would definitely be interested in a combined assistantship and resident training, as stated in Section II, Paragraph 3, in the Information Bulletin published by The American Board of Orthopaedic Surgery, revised in January 1946.

Since the last report, there has been no change in the total number of approved residencies, this number being approximately 450; but there are at the present time about ten additional hospitals, with approximately fifteen residencies, that are in the process of being approved by the Board and the Council on Medical Education and Hospitals of the American Medical Association. The Board has stated that, if a hospital has been approved for resident training, the decision will be left to the hospital regarding the number of residents they wish to train. This will enable many of the hospitals to train additional men without further approval.

Since the last report, this Office has been notified of only five vacancies. There are, however, still being established new resident training services in the Veterans Hospitals, which will have many new appointments to make. From the information this Office has had, some of these Veterans Hospital services are going to afford excellent training for the residents. Many Veterans Hospitals now have full-time Board Diplomates as chiefs of service.

The Office continues to receive requests for the names of fully trained orthopaedic surgeons to fill permanent locations. The Secretary will greatly appreciate hearing from men who have taken their full training and wish locations for practice.

FOR THE COMMITTEE ON POSTGRADUATE
TRAINING IN ORTHOPAEDIC SURGERY
A. R. Shands, Jr., M.D., Secretary

THE INTER-AMERICAN ORTHOPAEDIC FELLOWSHIP PROGRAM

The Committee on Inter-American Fellowships in Orthopaedic Surgery, representing The American Orthopaedic Association and The American Academy of Orthopaedic Surgeons, has been forced to discontinue its fellowship program for the present, because of overcrowded conditions in American teaching centers.

During the three years in which this fellowship program was operating, eighteen Latin American students of orthopaedic surgery spent from six months to two years in various teaching centers in the United States. The whole experience was most beneficial from the standpoints of both the students and the faculties involved.

The funds for support of this orthopaedic fellowship program were generously provided by the W. K. Kellogg Foundation of Battle Creek, Michigan. In addition to a monthly stipend, each student's expenses were paid while he attended an annual meeting of The American Academy of Orthopaedic Surgeons. At the end of his period of training, each fellow was accorded a travel period of a month on an itinerary of his own selection.

While in the United States this group of students organized an Orthopaedic Correspondence Club, which they expect to continue after returning home and which should prove to be of distinct professional and social value to them and to their respective communities.

Such a sponsored fellowship program has the wholehearted endorsement of the Department of State. Undoubtedly it is of value in giving concerted guidance to the visiting students of orthopaedic surgery. It is unfortunate that the program must be curtailed, even temporarily, as many applications have had to be rejected from foreign students hopeful of such an opportunity.

Oscar Lee Miller, M.D., Chairman

News Notes

The Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held at the Palmer House, Chicago, from January 25 through 31, 1947. It is expected that the guest speaker will be Sir Reginald Watson-Jones. The Instructional Courses, under the Chairmanship of Dr. Walter P. Blount, will be given on January 25 and 26. Further information may be obtained from the Secretary, Dr. Myron O. Henry, 401 Medical Arts Building, Minneapolis, Minnesota.

The **Atlas of Orthopedic Pathology** was prepared in 1943, at the Army Medical Museum, by Major D. M. Angevine and Colonel J. E. Ash, from material in The Registry of Orthopaedic Pathology. Its publication was sponsored by The American Academy of Orthopaedic Surgeons and The American Board of Orthopaedic Surgery. Copies are still available, and may be purchased from Dr. Joseph A. Freiberg, 707 Race Street, Cincinnati 2, Ohio. The price is $5.00 per copy, and remittance should be sent with the request.

Dr. M. N. Smith-Petersen has recently returned to Boston after spending several months in Norway. While there Norway's highest honor, that of Commander of the Royal Order of St. Olav, was bestowed upon Dr. Smith-Petersen by King Haakon.

Dr. J. E. M. Thomson, of Lincoln, Nebraska, who went to Czechoslovakia as a member of the Unitarian Medical Teaching Mission, and other members of the Mission were awarded the highest recognition of the Czechoslovakian Republic,—that of the Order of the White Lion, given by the government for distinguished service. Dr. Thomson was also a guest speaker at the congress of the *Československa Společnost Ortopedicka* held on August 28, 29, and 30, and was elected to honorary membership in the society.

The American Board of Orthopaedic Surgery will hold its next examination (Part II) at Chicago, Illinois, on January 22, 23, and 24, 1947. The deadline for receipt of completed formal applications and application fees is November 1, 1946. Letters of request and applications received after this date cannot be accepted. Correspondence and applications related to Part II of the examination should be sent to the Secretary, Dr. Francis M. McKeever, 1136 West Sixth Street, Los Angeles 14, California.

ARMY INSTITUTE OF PATHOLOGY AND AMERICAN REGISTRY OF PATHOLOGY

What is now known as the Army Institute of Pathology was established in 1863 as the Army Medical Museum. During World War II the activities of the Institute were greatly expanded, especially in the field of diagnostic pathology and research. There are now on file over 170,000 accessions. The results of research at the Institute during the past few years will be published in a volume of about 1400 pages as a part of the official history of World War II.

On request of Major General Norman T. Kirk, The Surgeon General of the Army, the Committee on Pathology of the National Research Council, Division of Medical Sciences, in late 1945 prepared a report on the future development of the Institute. The report has been approved by The Surgeon General and by the War Department.

The essential recommendations in this report are: (1) that a new building of adequate size be constructed; (2) that the Institute be organized in four divisions—Department of Pathology, Army Medical Illustration Service, Army Medical Museum, and American Registry of Pathology—each headed by a competent specialist; (3) that the staff of the Institute be drawn from both the commissioned ranks of the Army and from the civilian professions; (4) that a comprehensive educational and training program be undertaken; (5) that the vast store of material at the Institute be used for research; and (6) that the services in pathology in the Veterans' Hospitals be centralized at the Institute.

The American Registry of Pathology, founded in 1922, thus is, and will continue to be, an integral part of the Army Institute of Pathology. There were, on January 1, 1946, over 43,000 cases registered.

At the present time the American Registry of Pathology comprises fourteen registries. One of these is the Registry of Orthopaedic Pathology, established in 1943 and sponsored by The American Academy of Orthopaedic Surgeons.

All specimens in the Registry are available for review and research by competent investigators. Sets of slides and accompanying syllabuses on special fields are available for loan to the civilian professions and officers in the federal services. Physicians, dentists, and veterinarians are urged to send unusual specimens together with an abstract of the history to the Registry. The contributor receives a report on each specimen and is asked to keep the Registry informed of the follow-up on the patient.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Fifty-Ninth Annual Meeting of The American Orthopaedic Association, under the Presidency of Dr. J. Albert Key, was held at The Homestead, Hot Springs, Virginia, June 27, 28, and 29, 1946. Two symposia were presented and a number of papers were read, as follows:

THURSDAY, JUNE 27

Morning Session

Another Treatment for Congenital Flat Feet.
James E. M. Thomson, M.D., Lincoln, Nebraska (read by J. Warren White, M.D., Greenville, South Carolina).
Discussion: Lenox D. Baker, M.D., Durham, North Carolina (by invitation);
J. Warren White, M.D., Greenville, South Carolina.

The Definition of Human Locomotion on the Basis of Measurement, with Description of Oscillographic Method.
R. Plato Schwartz, M.D., Rochester, New York.
Discussion: Verne T. Inman, M.D., San Francisco, California (by invitation);
Robert W. Johnson, M.D., Baltimore, Maryland;
Arthur Steindler, M.D., Iowa City, Iowa.

Hypermobile Flat Foot with Short Tendo Achillis (HFF–STA).
Robert I. Harris, M.B., Toronto, Ontario, Canada;
Major T. Beath, M.C., Toronto, Ontario, Canada (by invitation).
Discussion: Frank D. Dickson, M.D., Kansas City, Missouri;
Edwin W. Ryerson, M.D., Chicago, Illinois;
John R. Moore, M.D., Philadelphia, Pennsylvania;
John L. McDonald, M.D., Toronto, Ontario, Canada;
J. Warren White, M.D., Greenville, South Carolina;
Compton Riely, M.D., Baltimore, Maryland;
Fremont A. Chandler, M.D., Chicago, Illinois;
Halford Hallock, M.D., New York, N. Y.;
Robert I. Harris, M.B.

Pre-Employment Back Examinations.
Steele F. Stewart, M.D., Honolulu, Hawaii.
Discussion: Philip Lewin, M.D., Chicago, Illinois;
Steele F. Stewart, M.D.

Active Splinting of the Hand.
Sterling Bunnell, M.D., San Francisco, California (by invitation).
Discussion: Philip D. Wilson, M.D., New York, N. Y.;
Sterling Bunnell, M.D.

Evening Session

Symposium on the Intervertebral Disc.
Arthur G. Davis, M.D., Erie, Pennsylvania, *Chairman.*
End-Result Study of the Intervertebral Disc.
Raymond E. Lenhard, M.D., Baltimore, Maryland (by invitation).
Ruptured Intervertebral Disc and Sciatic Pain.
Joseph S. Barr, M.D., Boston, Massachusetts.
The Disc Factor in Low-Back Pain with or without Sciatica.
J. Grafton Love, M.D., Rochester, Minnesota (by invitation).
An Analysis and Differentiation of Low-Back Pain in Relation to the Disc Factor.
Arthur Steindler, M.D., Iowa City, Iowa.
Diagnosis by Myelography in Disc Lesions.
Lt. Colonel Aubrey O. Hampton, M.C., A.U.S. (by invitation).
Pathological Studies on Intervertebral Discs.
Charles Eckert, M.D., St. Louis, Missouri (by invitation);
Alfred Decker, M.D., St. Louis, Missouri (by invitation).
Anatomico-Physiological Aspects of Injuries to the Intervertebral Disc.
Verne T. Inman, M.D., San Francisco, California (by invitation);
J. B. deC. M. Saunders, M.B., San Francisco, California (by invitation).

Discussion: William Jason Mixter, M.D., Boston, Massachusetts (by invitation);
Theodore A. Willis, M.D., Cleveland, Ohio;
Barnes Woodhall, M.D., Durham, North Carolina (by invitation);
Halford Hallock, M.D., New York, N. Y.

FRIDAY, JUNE 28

Morning Session

Future Development of Postgraduate Training in Orthopaedic Surgery.
Ralph K. Ghormley, M.D., Rochester, Minnesota.
Discussion: Guy A. Caldwell, M.D., New Orleans, Louisiana;
A. R. Shands, Jr., M.D., Wilmington, Delaware;
Steele F. Stewart, M.D., Honolulu, Hawaii;
Theodore A. Willis, M.D., Cleveland, Ohio;
Philip D. Wilson, M.D., New York, N. Y.;
Robert I. Harris, M.B., Toronto, Ontario, Canada;
Ralph K. Ghormley, M.D.

Report of the Committee on Infantile Paralysis.
Robert W. Johnson, M.D., Baltimore, Maryland.
Discussion: A. R. Shands, Jr., M.D., Wilmington, Delaware;
A. Bruce Gill, M.D., Philadelphia, Pennsylvania;
Robert W. Johnson, M.D.

The Newer Pathological and Physiological Concepts on Anterior Poliomyelitis and Their Clinical Interpretation.
Arthur Steindler, M.D., Iowa City, Iowa.
Discussion: H. Relton McCarroll, M.D., St. Louis, Missouri;
William T. Green, M.D., Boston, Massachusetts;
Arthur Steindler, M.D.

End Results Following Bone-Grafting for Non-Union of Carpal Scaphoid.
Gordon Murray, M.D., Toronto, Ontario, Canada (by invitation).
Discussion: Robert I. Harris, M.B., Toronto, Ontario, Canada;
Edwin F. Cave, M.D., Boston, Massachusetts.

President's Address.
J. Albert Key, M.D., St. Louis, Missouri.

Afternoon Session

The Evaluation of Cortical and Cancellous Bone as a Grafting Material: A Clinical and Experimental Study.
LeRoy C. Abbott, M.D., San Francisco, California;
Edwin R. Schottstaedt, M.D., San Francisco, California (by invitation);
J. B. deC. M. Saunders, M.B., San Francisco, California (by invitation);
Frederic C. Bost, M.D., San Francisco, California.
Discussion: Ralph K. Ghormley, M.D., Rochester, Minnesota;
Fremont A. Chandler, M.D., Chicago, Illinois;
LeRoy C. Abbott, M.D.

Survival in Bone Sarcoma.
Harry Platt, F.R.C.S., Manchester, England.
Discussion: Dallas B. Phemister, M.D., Chicago, Illinois;
Philip D. Wilson, M.D., New York, N. Y.;
Henry W. Meyerding, M.D., Rochester, Minnesota;
Harry Platt, F.R.C.S.

Subtalar Bone Block (Arthrorisis) for Certain Types of Flat Feet. A New Operative Procedure.
C. J. Basile, M.D., Baltimore, Maryland (by invitation);
W. L. Waldrop, M.D., Baltimore, Maryland (by invitation);
Allen F. Voshell, M.D., Baltimore, Maryland;
Moses Gellman, M.D., Baltimore, Maryland (by invitation).
Discussion: Frank D. Dickson, M.D., Kansas City, Missouri;
Oscar L. Miller, M.D., Charlotte, North Carolina;
H. Relton McCarroll, M.D., St. Louis, Missouri;
Robert I. Harris, M.B., Toronto, Ontario, Canada;
Allen F. Voshell, M.D.;
C. J. Basile, M.D.

Fracture-Dislocation of the Ankle with Fixed Displacement of Fibula behind the Tibia.
David M. Bosworth, M.D., New York, N. Y.
Discussion: Oscar L. Miller, M.D., Charlotte, North Carolina;
Robert I. Harris, M.B., Toronto, Ontario, Canada.

Medical Electronics; Electromyographic Studies of Muscle Action Currents.
Nicholas S. Ransohoff, M.D., New York, N. Y.
Discussion: Arthur Steindler, M.D., Iowa City, Iowa.

SATURDAY, JUNE 29

Morning Session

Symposium on the Complications of Old Fractures of the Neck of the Femur and Their Treatment.
Philip D. Wilson, M.D., New York, N. Y., *Chairman.*

Complications of Fractures of the Neck of the Femur.
Harold B. Boyd, M.D., Memphis, Tennessee;
I. L. George, M.D., Memphis, Tennessee (by invitation).

The Pathology of Ununited Fractures of the Neck of the Femur.
Dallas B. Phemister, M.D., Chicago, Illinois;
Mary S. Sherman, M.D., Chicago, Illinois (by invitation).

Results of Treatment of Old Fractures of the Neck of the Femur by Bone Grafting Combined with Internal Fixation.
Robert I. Harris, M.B., Toronto, Ontario, Canada.

Non-Union in Fractures of the Neck of the Femur. Treatment by Schanz Osteotomy.
Walter P. Blount, M.D., Milwaukee, Wisconsin.

Results of Treatment by the Whitman Reconstruction Operation.
Arthur Krida, M.D., New York, N. Y.

Arthrodesis of Hip for Ununited Fractures.
A. Bruce Gill, M.D., Philadelphia, Pennsylvania.

Results of Treatment by Vitallium Mold Arthroplasty.
M. N. Smith-Petersen, M.D., Boston, Massachusetts;
William A. Law, M.B., Liverpool, England (by invitation).

Results of Treatment by Trochanteric Arthroplasty.
Philip D. Wilson, M.D., New York, N. Y.

Hexagonal Method of Osteotomy.
James Dickson, M.D., Cleveland, Ohio.

Discussion: Harry Platt, F.R.C.S., Manchester, England;
Carl E. Badgley, M.D., Ann Arbor, Michigan;
Paul C. Colonna, M.D., Philadelphia, Pennsylvania;
W. W. Plummer, M.D., Buffalo, New York;
Harold B. Boyd, M.D.;
Mary S. Sherman, M.D.;
Walter P. Blount, M.D.;
Philip D. Wilson, M.D.

On Friday evening, June 28, the Annual Association Banquet was held, and on Thursday and Saturday, at noon, there were Executive Sessions.

LeRoy C. Abbott, M.D., San Francisco, California, is President of the Association for the coming year.

Officers, members to committees, and new members were elected, as follows:

Officers

President-Elect: Robert I. Harris, M.B., Toronto, Ontario, Canada;
Vice-President: Harold R. Conn, M.D., Akron, Ohio;
Secretary: C. Leslie Mitchell, M.D., Detroit, Michigan;
Treasurer: Frank D. Dickson, M.D., Kansas City, Missouri.

Committee Members

Membership Committee:
A. R. Shands, Jr., M.D., Wilmington, Delaware (for the unexpired term of Guy A. Leadbetter, deceased);
William T. Green, M.D., Boston, Massachusetts.
Program Committee: Robert V. Funsten, M.D., Charlottesville, Virginia.
Research Committee: Halford Hallock, M.D., New York, N. Y.

Representatives

American College of Surgeons: William E. Gallie, M.D., Toronto, Ontario, Canada.

American Board of Orthopaedic Surgery: Fremont A. Chandler, M.D., Chicago, Illinois (Clarence H. Heyman, M.D., Cleveland, Ohio, Alternate).

New Members

Rufus H. Alldredge, M.D., New Orleans, Louisiana;
Lenox D. Baker, M.D., Durham, North Carolina;
George O. Eaton, M.D., Baltimore, Maryland;
John A. Heberling, M.D., Pittsburgh, Pennsylvania;
Raymond E. Lenhard, M.D., Baltimore, Maryland;
William M. Roberts, M.D., Gastonia, North Carolina;
Walter G. Stuck, M.D., San Antonio, Texas.

CHARLTON WALLACE

1872–1946

Among the many orthopaedic surgeons in New York City who have contributed to the betterment of the specialty, Dr. Charlton Wallace deserves more than passing notice. A native of Kentucky, Dr. Wallace possessed much of the social charm so commonly associated with the southern gentleman of the old school. His medical degree was obtained from the College of Physicians and Surgeons, Columbia University, in 1898. The respect in which his classmates held him was shown when they elected him as permanent president of his class.

Dr. Wallace's training in the special branch of surgery which he followed was received, for the most part, at the Hospital for the Ruptured and Crippled, where he served first as assistant and later became Attending Orthopaedic Surgeon. He was also on the staffs of the Polyclinic Hospital, New York City, and St. Agnes Hospital, White Plains, New York. His prime interest was in crippled children, and he devoted his life to them.

From 1905 to 1913 he was Orthopaedic Surgeon in charge of the East Side Free School for Crippled Children. In the early part of his career, he was in charge of experimental work in orthopaedics at Sea View Hospital. He was instrumental in establishing the Neponsit Beach Hospital for Children, Rockaway Beach. He was surgeon in charge of establishing the St. Charles Hospital for Crippled Children, Port Jefferson, Long Island, and was Chief Surgeon from 1907 to 1920. As a result of his interest in the rehabilitation of those disabled through industry and accidents, he was a member of the staff of the Reconstruction Hospital in New York from 1918 to 1923. Since 1929, he had been Surgeon-in-Chief of the New York State Reconstruction Home, West Haverstraw, an institution which he had helped to plan for the betterment of crippled children. He was Professor of Orthopaedic Surgery at Cornell University Medical College from 1913 to 1935.

Dr. Wallace died at his home in Chappaqua, New York, on August 16, 1946.

At the time of his death, he was Professor of Orthopaedic Surgery, New York Polyclinic Medical School and Hospital; and Consulting Orthopaedic Surgeon at the Hospital for Special Surgery, St. Charles Hospital for Crippled Children, St. Agnes Hospital, and Stamford Hospital in Stamford, Connecticut. He was a member of the New York Academy of Medicine, a Diplomate of The American Board of Orthopaedic Surgery, and a Fellow of the American College of Surgeons and of The American Academy of Orthopaedic Surgeons. He had been active as a member of The American Orthopaedic Association since 1907, but for the past few years was an Emeritus Member.

ROYAL WHITMAN

1857–1946

Royal Whitman was born in Portland, Maine, on October 24, 1857. He received his degree of Doctor of Medicine from Harvard Medical School in 1882, and for a while he practised in Boston. He was a charter member of the Tavern Club in Boston. He went to New York in 1889 and became associated with Dr. Virgil P. Gibney, at the Hospital for the Ruptured and Crippled. The association with this Hospital continued until 1929 when, after forty years of continuous service, he retired from both hospital and private practice. He moved to England, where he remained for about thirteen years, returning to his own country in 1943.

He died in New York City on August 19, 1946. Three days before his death he received an invitation to represent this country, as a guest of the French Government, at a meeting to celebrate the one hundredth anniversary of the founding of the French Academy of Surgery.

Dr. Whitman was a member of many medical organizations both here and abroad, but he valued most his Fellowship in the Royal College of Surgeons, and his membership in The American Orthopaedic Association, of which he was President in 1895.

He was an indefatigable worker. His was the opinion that, in orthopaedics, the out-patient department or clinic was an indispensable and integral part of the Service. The patients were seen first in the out-patient department and, after their stay in the Hospital for operative or non-operative treatment, returned to it for follow-up care or observation. This unit of service included both indoor and dispensary care. Hence, he, as well as all of his associates, attended the out-patient clinic. The clinic hours ran from one to three in the afternoon and so prompt was his arrival that watches could be set at one o'clock when he entered the Hospital. He had little patience with an assistant who came late or offered excuses for irregular attendance. In this, as in so many other respects, he set his assistants an excellent example.

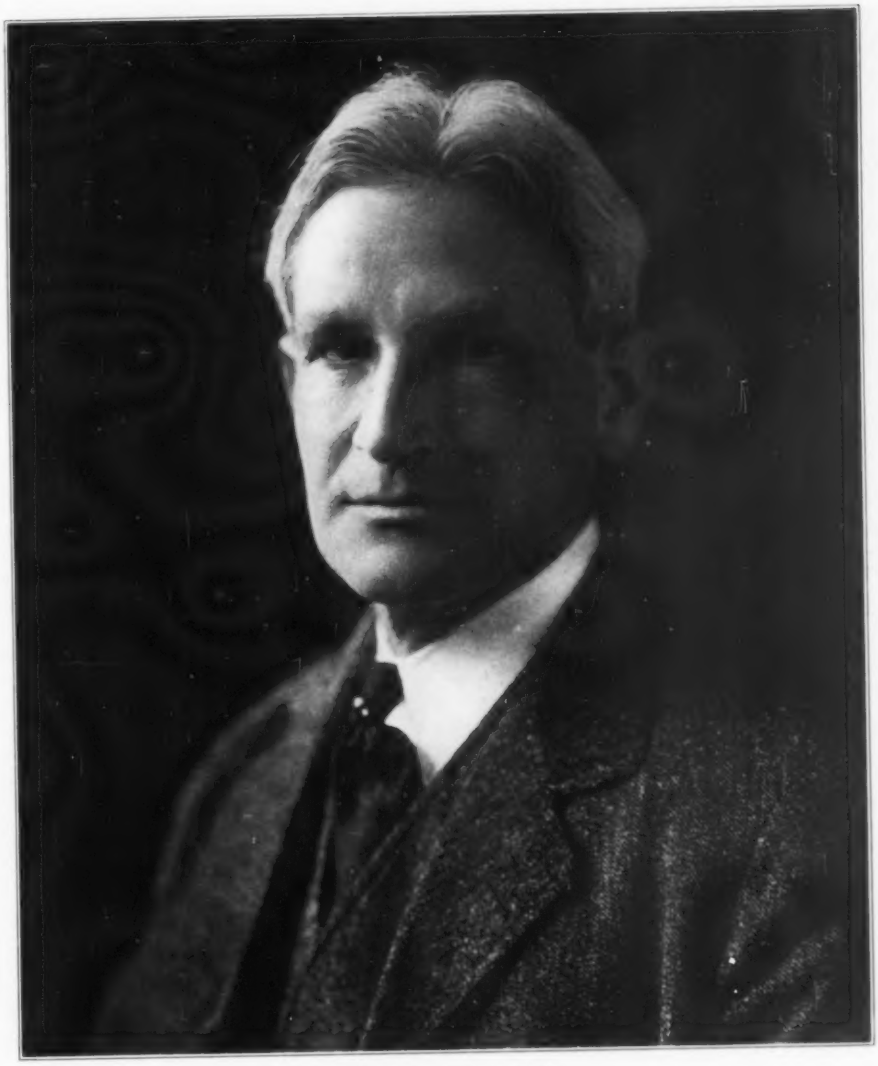
Dr. Whitman loved orthopaedic surgery and sought continuously and zealously to advance it. To those who saw him and worked with him four or five days a week, he seemed to be thinking of nothing but orthopaedics. During a lull in clinic work in the afternoons the subject discussed was never art, literature, music, or politics, but always orthopaedic surgery,—a difficult case for diagnosis, surgical technique, mechanical or surgical principles, or orthopaedic literature. Dr. Whitman read extensively and was thoroughly informed on the orthopaedic literature in English, French, and German; he expected all of his associates to be equally well informed and up to date, so that discussions, which were very frequent, would be most fruitful and thought-provoking.

Dr. Whitman was a profound student of orthopaedic surgery, a pioneer, and a pathfinder. He was always trying out new procedures,—either those he initiated or those suggested by others. He had an insatiable curiosity about the pathogenesis of orthopaedic diseases and deformities, and an imagination which led him continuously to seek new methods of manipulative or surgical correction of musculoskeletal defects. He was his own sternest critic and never reported favorably upon any technique or procedure until he himself was thoroughly convinced of its usefulness. When he became convinced of the value of any treatment, he would, through addresses or medical essays, hammer away at the profession until his opinion was accepted.

Despite his intense interest in operative surgery, he never overlooked the opportunities and advantages of manipulative treatment or the manual correction of deformities, of which he was a master. Although short of stature and thin, he many times surprised his young and more vigorous assistants by the rapidity and ease with which he would correct a resistant deformity over which they had labored ineffectually. In the days when the use of great manual force was condoned in the correction of a club foot or the reduction of a congenital dislocation of the hip, he exhibited remarkable dexterity and strength in overcoming manually the resistance of contracted tissues and overcorrecting a deformity.

Dr. Whitman was particularly insistent upon a thorough knowledge of mechanical principles, the pathology of deformities, and the observance of these in therapeusis. Braces to him were intended for the support of the trunk or limbs, and not for the correction of deformities. First an equinovarus of the foot, a flexion at the hip or the knee, or a rigid flat foot had to be corrected; then, and then only, might the surgeon apply a brace. Woe to the assistant who did not obey this rule!

Dr. Whitman was truly a master surgeon. He was second to none in speed, dexterity, thoroughness, and careful handling of tissues. He religiously avoided undue or excessive trauma, and was ever mindful of the fact that the recovery of tissues operated upon depended directly upon the gentleness with which they were treated. "Treat the tissues lovingly" was the unwritten but ever-present motto of the amphitheater. Two factors contributed outstandingly to Dr. Whitman's ease and speed at the operating table. He was an excellent anatomist and, through hints dropped here and there, it was evident that he



ROYAL WHITMAN

kept reviewing anatomy; second, on the day before an operation he continuously reviewed what he contemplated doing, and hence he came to the operating table with a definite plan of procedure. He avoided complicated operations, believing that the goal could be attained through simple measures. He always avoided multiple operations at one session, on the basis that the usual orthopaedic operation was rarely an emergency procedure, and that the end result would be better if he used several simple separate operations.

He taught orthopaedic surgery for forty years, both at the College of Physicians and Surgeons of Columbia University and at the Hospital for the Ruptured and Crippled. His love for orthopaedic surgery made him a most generous teacher, who sought to transmit his experiences and information to whoever showed an interest and would listen. His method of teaching was not always a placid procedure. He often used the difficult, and not always agreeable, method of sarcastic criticism. This at times was vexing. His students, however, soon recognized the light in his eyes and the smile on his lips, and knew that there was no malice in the sarcasm. He meant only to emphasize indelibly some point in observation, diagnosis, or surgical technique. To the less understanding students and visitors, this pedagogic method was disconcerting. Those who knew Dr. Whitman well, however, realized that when he was sarcastic he would teach much.

As an investigator and teacher, Dr. Whitman was undoubtedly one of the great contributors to the advancement of orthopaedic surgery in our country. His text book on orthopaedic surgery is a classic. Dr. Whitman contributed a great many essays on orthopaedic problems. These were published in

English, but often were translated or abstracted in foreign languages, so that his teachings went to every corner of the world and to all medical circles. Dr. Whitman originated several methods of treatment, which have been universally acknowledged and adopted as classical procedures in orthopaedic surgery. He initiated the abduction treatment for fractures at the hip. His insistence on a method which created the opportunity for repair of a fractured hip gave the impetus to extensive clinical research and to the splendid progress which has been made in the last two decades in the management of fractures at the hip. He devised the operation of astragalectomy and backward displacement of the foot for paralytic calcaneus,—an operation which formerly was generally accepted for stabilization of the paralytic calcaneus foot. Dr. Whitman's exhaustive studies on flat or weak feet led to the establishment of a most effective system of treatment, including the use of the Whitman foot brace. His contributions to orthopaedic surgery become incalculable when one contemplates the many physicians whom he instructed and inducted into productive orthopaedic surgery.

In the death of Dr. Royal Whitman, orthopaedic surgery has lost an ardent and profound student, a splendid teacher, and a master surgeon. His legacy to his students is a love for orthopaedic surgery, devotion to the physically handicapped, and a determination to cure the cripple.

HERBERT ALTON DURHAM

1884–1946

Dr. Herbert Alton Durham died suddenly at Shreveport, Louisiana, on March 13, 1946, at the age of sixty-two. He was Surgeon-in-Chief of the Shriners' Hospital in Shreveport and an outstanding orthopaedic surgeon. Dr. Durham spent his boyhood on a farm in Vermont and received the degrees of A.B. in 1905 and M.D. in 1909 from the University of Vermont. After serving a general internship, he became a resident at the New York Orthopaedic Hospital. Dr. Russell H. Hibbs was Chief Surgeon of the Hospital at that time, and had just announced his operation for spine fusion. He was impressed by Durham's ability and, at the completion of his residency, sent him abroad on a travelling fellowship. The greater part of the year was spent in England under Sir Robert Jones, and in Austria and Germany.

With the onset of the first World War in 1914, he returned to New York and became a member of the staff of the New York Orthopaedic Hospital. When the United States entered the War, Durham was at once commissioned in the Army and went to England with the first contingent of orthopaedic surgeons under the leadership of Dr. Joel E. Goldthwait. Durham served under Sir Robert in a British Military Hospital until the end of the War, when he again returned to the New York Orthopaedic Hospital, this time as an Attending Surgeon.

In 1923 he was appointed Surgeon-in-Chief of the Shriners' Hospital at Shreveport, Louisiana, in which capacity he served until his death. He also was attending orthopaedic surgeon at the Highland, North Louisiana State, and Tri-State Sanitaria. He was an exceptionally skillful technician and a capable mechanic. These qualities, combined with a sound surgical judgment, accounted for his great success and his high reputation. He devised an apparatus for leg lengthening, an operation for correction of internal rotation of the hip in spastic paralysis, and a technique for transplantation of the biceps femoris.

He was a member of The American Academy of Orthopaedic Surgeons and of the American Medical Association, a Fellow of the American College of Surgeons, and a member of the Clinical Orthopaedic Society and of the Eastern State Orthopaedic Club. He was an out-of-doors man and got his recreation by shooting, riding, and golf.

He is survived by his wife, Beatrice Anderson Durham, to whom he was married in England in 1918, and by two children, Lieutenant Herbert A. Durham, Jr., of the Army Air Force, and Mrs. Harry V. Bascom of Shreveport.

Current Literature

HUMAN EMBRYOLOGY. Bradley M. Patten, Ph.D. Philadelphia, The Blakiston Company, 1946. $7.00.

This monumental work of scientific scholarship, by the distinguished Professor of Anatomy in the University of Michigan Medical School, is a complement and sequel to his previously published and well-known volumes on the embryology of the chick and of the pig. Not only is the text authoritative and final, but it is richly illustrated with drawings and photographs, mostly original, made by the author or under his supervision, of which fifty-three are in color. There is an elaborate bibliography of over one thousand titles.

Especial attention is devoted to the circulatory and nervous systems, upon which Dr. Patten has done much original research. The book is a model of lucid exposition, including within compact limits the essence and details of so vast and complex a subject. It is a masterpiece,—a memorable contribution to the knowledge of human embryology.

ENTORSES DU COU-DE-PIED ET ENTORSES DU GENOU. INTRODUCTION A L'ÉTUDE DE L'ARTHROGRAPHIE (Sprains of the Ankle and Sprains of the Knee. Introduction to the Study of Arthrography). L. Léger et C. Olivier. Paris, Masson et Cie, 1945. 200 francs.

During our modern ways of living—with war, sports, and increasing numbers of youth organizations—sprains of the joints are becoming more and more frequent, and the majority of them occur in the ankle and the knee joint. Their diversity is very great; their study, although begun several centuries ago, has always left the practitioner at a loss, not only about their classification, but especially about their treatment. One of the merits of this book lies in the fact that Léger and Olivier have observed a great many such sprains and have been especially interested in their surgical treatment. The main features of the publication are those which characterize a French mind,—clearness, logic, and the didactic spirit. Its value is increased by the completeness of the study.

In the first chapter the authors study sprains of the ankle, with which, of course, they include the tarsus. They review consecutively the macroscopic and microscopic pathology, the physiopathology, etiology, mechanism, clinical study, complications, diagnosis, evolution, and treatment. One of the main features of this chapter is a very complete study of the ideas of Leriche, which have been prevalent during the last few years. The authors have reduced them to their just proportion, and have come to the conclusion that the anatomical findings prove the frequent presence—if not the constant presence—of macroscopic lesions in the ligaments going from the elongation to the disinsertion, with or without partial or complete rupture. They describe the various treatments in detail,—the physiotherapeutic procedures; the various bandages, which are amply illustrated; the treatment by novocain injection; the importance of relative immobilization; and the various surgical interventions, about which they show some skepticism. The sequelae of this type of sprain are described,—namely, laxity of the ligaments, diastasis, chronic arthritis, painful osteoporosis, and posttraumatic ossification.

The authors adopt the same plan in discussing sprains of the knee joint. Their study of the relative frequency of lesions of the lateral ligaments and the cruciate ligaments is very detailed, but in this chapter a most extensive and personal study is made of arthrography. Although the authors make a very judicious evaluation of the different non-surgical treatments—the infiltration of novocain, which they consider as a symptomatic treatment, immobilization, and physiotherapy—they give to surgical procedures the most important value.

More than fifty pages are devoted to "old sprains". The reader's attention is directed toward the diagnosis and surgical treatment of "unstable knees", and the authors review the different types of tenoplasty and tendon replacement, mentioning, among others, the names of Hey Groves, Mauck, and Bennett. Under "painful knees" is included a discussion of Pellegrini's disease. Chronic arthritis and traumatic lipo-arthritis are also considered. In this chapter the authors show a very marked tendency toward surgery.

This book does not include a statistical study or a bibliography, but it is so clear and practical that it will be read with interest not only by orthopaedic surgeons, but also by the general practitioner.

MEDICAL EDUCATION AND THE CHANGING ORDER. Raymond B. Allen, M.D., Ph.D. New York, The Commonwealth Fund, 1946. $1.50.

The Challenge to Medical Education is the title of the first chapter of this small volume. In it the author, who is Executive Dean of the Colleges of Dentistry, Medicine, and Pharmacy at the University of Illinois, makes many interesting general observations:

"The study of medicine . . . must embrace the study of life in all its aspects—physical, psychological, and social."

"Changes in medical education in this country reflect changing cultural, scientific, social, economic,

and political conditions and follow an evolutionary—rather than a revolutionary—pattern typical of American institutions generally. The current problem is to identify, strengthen, and secure the wider acceptance and application of those trends in medical education and medical science which best serve the needs of the people."

"Medical education, like medical science, is an experimental art dependent wholly for success on the learning, skills, imagination, resourcefulness, integrity, and courage of individuals."

The historical background and foundations of medical education are discussed at length. In order are considered the preparation for the study of medicine, the essential factors in undergraduate medical education and in graduate study, the problems in medical education, and opinions about their solution.

The author makes a plea for the adequate support of medical education and research. He points out, too, the responsibility of American medicine in tomorrow's world: "The hopeful and talented of many lands will need and want opportunities to study in our universities; we must make this possible to the limit of our resources. We must help, too, in the reestablishment of our sister institutions in war-ravaged countries—particularly of their libraries. We must without stint pay our debt to the scholarship, science, and humanism of Europe without which there would be no western civilization. We should not deny this obligation because a misguided few have allowed their science and scholarship to serve the ends of tyranny. The medicine, science, and scholarship of tomorrow's world must forever be free to serve the peaceful needs of all mankind."

This is one of the monographs issued by the Committee on Medicine and the Changing Order of the New York Academy of Medicine. It is well written and merits a wide reading.

MANUAL OF DIAGNOSIS AND MANAGEMENT OF PERIPHERAL NERVE INJURIES. Robert A. Groff, M.D., and Sara Jane Houtz, B.S. Philadelphia, J. B. Lippincott Company, 1945. $6.00.

This book represents an amazing feat on the part of the authors, since it was written during a period of intensive clinical activity at the worst period of the year—the monsoon season—in Burma. They were presumably attempting to have available for the Military Services, in time for the expected invasion of Japan, a useful guide in methods of examination of peripheral-nerve injuries. The unforeseen end of World War II must have made them wonder if publication of the work was warranted, but whatever its current usefulness may be, it forms an impressive testimonial to their industry under adverse circumstances.

Nearly half of the book is devoted to a series of diagrams, indicating the proper method of examination of most of the voluntary muscles of the body. This is the most useful part of the volume; it represents an extension of the series of pictures published by the Medical Research Council of Great Britain under the title of "Aids to the Investigation of Peripheral Nerve Injuries", and includes more of the musculature. It is not surprising that the authors, engaged as they were in the practical problems of treating wounded soldiers, placed such emphasis on teaching their personnel exactly how to examine muscle strength. When a more leisurely and definitive volume on peripheral-nerve injuries appears, incorporating all of the lessons learned in this War, it is to be hoped that it will include pictures, illustrating examinations of specific muscles, as complete as those in this book and as clear as those in the pamphlet of the Medical Research Council.

The authors have discussed only briefly the value of the various methods of electrodiagnosis and of management of peripheral-nerve injuries, proposed during World War II, realizing that only after follow-up studies have been completed on the thousands of cases handled can the true end results be determined.

They do advocate one obsolete procedure, to which their attention should be drawn. On page 57 they state that the inferior cervical ganglion and the upper two thoracic sympathetic ganglia are removed for causalgic pain in the upper extremity. It has long since been shown by J. C. White that this postganglionic sympathectomy (which unnecessarily denervates the head as well, and produces a Horner's syndrome) should be abandoned in favor of a preganglionic operation, with division of the sympathetic trunk below the third thoracic ganglion and of the rami communicantes to the second and third thoracic ganglia.

THE AMERICAN HOSPITAL. E. H. L. Corwin, Ph.D. New York, The Commonwealth Fund, 1946. $1.50.

This monograph is one of a series of studies issued under the auspices of the Committee on Medicine and the Changing Order of the New York Academy of Medicine. In its 226 pages there is an abundance of information about the American hospital, past and present, with the trends indicating the pattern for the future. From the small beginning of 178 hospitals (146,472 patients) in 1873, when the first list of hospitals in the United States was compiled, the number had grown in 1943 to 4,655 (15,374,698 patients), with corresponding increases in physical assets and capital investment. The greatest single impetus to hospital growth was the evolution of surgery; in 1942, 44.7 per cent. of hospital patients were surgical cases.

Among the topics discussed are the types of hospitals, with the general hospital constituting the largest group; the financial structure; hospital planning and construction; and the distribution and

utilization of hospitals. A chapter is devoted to the Outpatient Department, which has superseded the dispensary. This Department, which reaches as many patients as does the hospital, affords the best opportunity for the practice of preventive medicine. In general, its value as an educational medium has not been fully realized. The importance of the hospital as a teaching center and the problem of the chronically ill are also stressed.

In the closing chapter, Retrospect and Prospect, the entire volume is fully summarized, with brief comment on the many phases previously discussed.

The importance of the hospital in the health of the community and as a training center, under changing conditions which are partly the result of the War, makes this book of value to those interested in the field of medicine and the care of the sick.

LA INMOVILIZACION ENYESADA. SU TÉCNICA Y SUS APLICACIONES (Plaster Immobilization: Its Technique and Its Uses). Nino Valentin Zucchi. Buenos Aires, "*El Ateneo*", 1945.

This volume, dedicated to the memory of Vittorio Putti, seeks to show how to use plaster-of-Paris bandages in the treatment of disabilities in all parts of the body. The author, from his experience in the Traumatological Institute in Montevideo, Uruguay, feels that its use is not well known and that casts are frequently applied badly, to the harm of the patients. After discussing its discovery by Mathijsen and the chemistry of anhydrous calcium sulfate, the author describes many types of apparatus designed to facilitate the making of plaster casts for different parts of the body.

Numerous excellent illustrations are given; one, in particular, shows the areas of the body which should be padded when plaster casts are applied. The technique of applying edging, straps, and buckles is well described. Patterns for making special plaster molds for the facial bones and other special parts of the body are shown.

This is a complete treatise on plaster application. It is modeled on the older European texts, and reminds one of Calot's treatise. It is far more adequate in its treatment and illustrations than is any extant treatise in English. One can recommend it as a helpful text to anyone who uses plaster-of-Paris casts.

A COMPLETE OUTLINE OF FRACTURES, INCLUDING FRACTURES OF THE SKULL. J. Grant Bonnin, M.B., F.R.C.S. Ed. 2. London, William Heinemann Ltd., 1946. 30 shillings.

This is a straightforward, systematic, comprehensive, and well-illustrated book. It will be useful to the surgeon, especially the occasional surgeon, but it is probably presented in too much detail for most students. In general the book is up-to-date. The author is wise in not being one season ahead of the fashion. He commendably avoids that misleading dogmatism and confident overstatement which have marred more than one great book on fractures. He has chosen a plastic surgeon, who speaks with authority on maxillofacial injuries, to write the chapter on fractures of the face and jaws.

A BIBLIOGRAPHY OF INFANTILE PARALYSIS, 1789–1944. Edited by Morris Fishbein, M.D.; compiled by Ludvig Hektoen, M.D., and Ella M. Salmonsen. Philadelphia, J. B. Lippincott Company, 1946. $15.00.

This bibliography, prepared under the direction of the National Foundation for Infantile Paralysis, traces the literature on poliomyelitis back to 1789, when the disease was first described. The references are arranged chronologically; as would be expected, the preponderance of the work on this subject has been published in the last ten years. As explained in the Preface, much of the foreign literature of the past few years is not yet available, so that a supplement to the bibliography is planned to take care of these references.

The volume contains more than 8000 references to publications on infantile paralysis. Since a short abstract of the article is included in most instances, the book will be invaluable to the worker in this field. In addition, a detailed, carefully prepared subject index, as well as an index of authors, adds immeasurably to the value of the volume. It is a fine piece of work, which will have extensive usefulness.

MEDICAL SERVICES BY GOVERNMENT. LOCAL, STATE, AND FEDERAL. Bernhard J. Stern, Ph.D. New York, The Commonwealth Fund, 1946. $1.50.

This book represents one of the studies undertaken by the Committee on Medicine and the Changing Order of the New York Academy of Medicine. It contains a wealth of factual data on the extent of medical care as provided by local community, state, and Federal Government.

The development of this service has been gradual. In the early days of the Colonies and of the United States, the care of the indigent sick was assumed by voluntary private philanthropy. As States were organized, they assumed this responsibility. Many of the state laws were based on the Elizabethan poor laws. The first hospitals in the United States were really infirmaries in poorhouses. The development of town or city, county, and state institutions preceded the establishment of Government-controlled institutions.

The United States Marine Hospitals represent the oldest venture of the Federal Government in

the field of medical care, and their operation was the initial function of the Public Health Service. Official Public Health Services concerned with the control and prevention of disease have developed throughout the years as a separate type of Government service.

New patterns of medical care are now being formulated, and the role of local, state, and Federal governments in the field is shifting. Dr. Stern traces these developments and indicates the changing emphasis and changing points of view concerning the relative responsibilities of the local community, the state government, and the Federal Government.

The recent wartime activities of the Federal Government have further extended Government medical services. The book closes with a summary of the medical services to veterans.

OCCUPATIONAL THERAPY FOR THE LIMBLESS. Phyllis Lyttleton, C.S.P., M.A.O.T. London, H. K. Lewis and Company, Ltd., 1946. 3 shillings.

This pamphlet of forty pages is an appeal for sympathetic understanding of the problems of the amputee. The author was an occupational therapist in one of the hospitals of the Ministry of Pensions, to which came patients "who had lost one arm, one leg, both hands, both legs, and [with] all possible combinations of these disabilities". She reports her experiences in adapting crafts for these patients, which were useful not only as therapy and to help pass the months of waiting until their prostheses were fitted, but also in building their hopes for the future.

The psychological approach to these patients is most important and is emphasized throughout the book. The author feels that the intelligent, sympathetic occupational therapist can make a real contribution to the reeducation of these patients, mentally as well as physically.

DEMONSTRATIONS OF OPERATIVE SURGERY FOR NURSES. Hamilton Bailey, F.R.C.S. Baltimore, The Williams and Wilkins Company, 1945. $3.50.

Practical demonstrations for student nurses were the basis of this excellent textbook. It will be especially interesting to those of the nursing profession who wish to excel in the technique and skill of work with surgeons. Any nurse would benefit by using this book as a reference, for it includes detailed descriptions of many operations; every operating-room nurse should include it in her professional library.

The illustrations are excellent and vividly portray most major operative procedures.

CURARE — INTOCOSTRIN. New York, E. R. Squibb and Sons, 1946.

This volume consists of a well-constructed collection of recent articles on curare. The subject matter includes fundamental research in the chemistry and pharmacology of the drug, and its therapeutic and clinical contributions. As an exhaustive reference source, this book will serve a very useful purpose, especially in light of the increased interest in the clinical applications of curare. No editorial opinion is expressed in relation to the collection of articles. In the form of an appendix, however, an attempt is made to correlate accepted experimental data on curare with the recent concepts of neuromuscular conduction. This discussion should prove of great interest to the clinician, but is, of course, largely speculative in approach.

ON THE DIFFERENT TYPES OF INTRACAPSULAR FRACTURES OF THE FEMORAL NECK. A SURGICAL INVESTIGATION OF THE ORIGIN, TREATMENT, PROGNOSIS AND COMPLICATIONS IN 365 CASES. Per Linton. *Acta Chirurgica Scandinavica*, **90**: Supplementum 86, 1944.

In a series of 365 fractures of the neck of the femur, 200 were followed in detail and seventeen were reported without roentgenograms. The mechanism of causation and the significance of abduction, intermediate, and adduction fractures are discussed. It is concluded that the determining factors were the force of the blow and the strength of the skeleton. Variation in direction apparently had little effect. The fractures differ more in degree of dislocation than in type.

Abduction fractures are frequently stable. The writer avoids the use of the term "impaction" and substitutes "stability", because of the pitfalls in undertreating these fractures. He recommends nailing abduction fractures, if there is any doubt of their stability.

The significance of the obliquity of the fracture line is discussed in great detail. Accurate methods of determination of the angle are necessary. Obliquity alone is not a conclusive factor in indicating a poor prognosis. Combined with too horizontal a position of the nail or a posterior defect, increased obliquity is associated with non-union in a significantly increased number of cases. The greatest factor in producing poor results is increased age.

The frequency of aseptic necrosis of the femoral head is greater in the fractures with pronounced displacement. In a comparative series in which multiple small nails were used, the frequency of aseptic necrosis was apparently less.

Four cases of subtrochanteric osteotomy, simultaneous with the reduction and fixation, are recorded. In two additional cases, an osteotomy was performed soon after the primary reduction and nailing. In all of these cases, a cast was applied to maintain the position of the osteotomy; the cast was the chief objection to the method. The results were good. The total frequency of union, in cases nailed according

to the method of Smith-Petersen and Johansson, was 83.6 per cent.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Reparative Surgery of Compound Battle Fractures in the Mediterranean Theater of Operations. Oscar P. Hampton, Jr. *Annals of Surgery*, **122**: 289–332, 1945.

This important article provides a comprehensive presentation of an organized plan for the surgical care of serious wounds. The program rests upon sound surgical principles, and the directions for its implementation are set forth. The paper is too comprehensive to be abstracted, but it should be read and studied by surgeons who deal with compound fractures. The author believes that, whatever the value of blood and penicillin may be as surgical adjuncts, further improvement in results probably depends upon perfection of surgery, for which there is no substitute.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

A Comparative Study of 100 Fractures of the Shaft of the Femur in Which One-Half Were Treated with Penicillin. Spencer A. Collom, Jr., and William McD. Ewing. *Annals of Surgery*, **122**: 773–792, 1945.

Of a series of 100 consecutive fractures of the femur, eighty-two were compound fractures. These compound fractures were studied in groups, arranged according to the treatment. The keynote of the treatment is sounded in the following quotation from Churchill (*Annals of Surgery*, **120**: 268, 1944): "A highly significant and far-reaching advance in military surgery has taken place in the base hospitals with the development of what may be called *reparative surgery*. Wounds left unsutured at the initial operation are routinely closed by suture, usually at the time of the first dressing. With the use of penicillin as a safeguard against infection, the management of wounds complicated by fracture or joint involvement has been revolutionized." The present study substantiates the conclusion that, while penicillin and blood are valuable aids in preventing local and systemic invasion by penicillin-sensitive organisms, they are not a substitute for adequate surgery. The value of reparative surgery is emphasized. This means secondary débridement and closure between the fifth and tenth days. The majority of fractures of the femoral shaft could be realigned by skeletal traction, but internal fixation was performed when indicated and the results were satisfactory. The time required for bone healing varied in proportion to the duration of wound sepsis.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

The Use of Penicillin in the Treatment of Acute Hematogenous Osteomyelitis in Children. Report of Twelve Consecutive Cases. Edward L. Compere, William J. Schnute, and Lee M. Cattell. *Annals of Surgery*, **122**: 954–962, 1945.

Hematogenous osteomyelitis in children from the age of three up to puberty usually originates in a skin lesion and is caused by hemolytic *Staphylococcus aureus* or *Staphylococcus albus*; this causes more bone damage than does the hemolytic streptococcus, which more often attacks children under the age of three. The sulfonamides have been shown to be useful in acute osteomyelitis, but some patients are sensitive to these compounds and in others the organism may be sulfonamide-resistant. Subsequent surgery has been required in many patients who apparently had been cured by the sulfonamides. In twelve consecutive patients, penicillin was successful; ten of these patients had been treated unsuccessfully with sulfonamides. Surgery of a minor nature was required in only four of the twelve cases. It is thought that penicillin is more effective than any other agent in acute osteomyelitis, but it must be emphasized that even its great value does not permit the omission of the well-established principles of medical and surgical care.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

The Pathogenesis of Localized Fibrous Lesions in the Metaphyses of Long Bones. C. Howard Hatcher. *Annals of Surgery*, **122**: 1016–1030, 1945.

In a careful study of forty-five patients with metaphyseal fibrous defects in the bones of the lower extremities, it was found that fourteen also had epiphyseal disorders. Spontaneous healing was the rule; surgical eradication was necessary for the relief of pain in a few cases. The evidence indicates that metaphyseal fibrous defects are not localized, as is commonly thought. While the primary causes are unknown, there is enough similarity between the metaphyseal and the epiphyseal lesions to suggest a common pathogenesis.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

Delayed Internal Fixation of Compound Battle Fractures in the Mediterranean Theater of Operations. A Follow-Up Study in the Zone of Interior. Oscar P. Hampton, Jr. *Annals of Surgery*, **123**: 1–26 and 238–275, 1946.

This is an extensive report of an end-result study of the use of delayed internal fixation in compound battle fractures. It merits reading in its entirety. The article substantiates the conclusion that a place has been established for delayed internal fixation. Of 332 fractures treated in accordance with this well-formulated program, the maximum achievable result was secured in 258 (77.2 per cent.). Complete figures on the series are given in comprehensive tables.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

THE INCIDENCE OF COMPLICATIONS IN THE USE OF TRANSFIXION PINS AND WIRES FOR SKELETAL TRACTION. Charles K. Kirby and William T. Fitts, Jr. *Annals of Surgery*, **123**: 27–31, 1946.

This is an encouraging report on the use of transfixing pins and wires. Three hundred and forty-two pins and wires were used in the treatment of 233 fractures of the long bones. Only one infection occurred,—an incidence of 0.33 per cent. Even in this case, neither osteomyelitis nor a draining sinus developed. There were a few minor complications, such as loosening, breaking, or slipping, but in no instance did these occurrences have any significant effect upon the course or the result.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

THE IMMERSION FOOT SYNDROME. C. C. Ungley, G. D. Channell, and R. L. Richards. *The British Journal of Surgery*, **33**: 17–31, 1945.

This paper records the results of cases treated during 1941 and 1942. "Immersion foot" is stated to be a descriptive, but inaccurate, term for a syndrome produced by exposure of the extremities to a degree of cold insufficient to freeze the tissues.

There are four stages in the typical case of immersion foot: the period of exposure, and the prehyperaemic, hyperaemic, and posthyperaemic stages. The feet are cold, numb, swollen, and pulseless during exposure and immediately afterward; this is believed to be due to intense vasoconstriction. The next stage is accompanied by intense hyperaemia, increased swelling, and severe pain. The hyperaemia decreases and the pain and swelling are lessened during a period of from seven to ten days after rescue. Due to damage to the peripheral nerves, disturbances in sensation, sweating, and muscular atrophy and paralysis then appear.

After several weeks the feet become very sensitive to cold and, if exposed to a low temperature, they may remain cold for several hours. Hyperhidrosis frequently appears with this stage, and occasionally blisters and gangrene.

The prognosis depends upon the severity of the damage. Rapid warming of the tissues is condemned. Cold therapy in the hyperaemic stage may give relief, but should not be used earlier. Sympathectomy should not be used early, but may have its place in the late cold-sensitive state.

The authors consider in great detail the pathology and the methods of prevention and treatment. Accompanying the article are many excellent tables and illustrations.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

THE MAJOR AMPUTATION STUMP IN HEALTH AND DISEASE. F. G. St. Clair Strange. *The British Journal of Surgery*, **33**: 31–41, 1945.

The ideal amputation stump is one that will allow the proper appliance to be worn without discomfort and without materially interfering with the patient's economic existence. The ideal lengths are stated as (1) below the knee, five and one-half inches from the joint line to the point of bone section; (2) above the knee, ten to twelve inches, measured from the tip of the greater trochanter; (3) below the elbow, seven inches from the tip of the olecranon; and (4) above the elbow, eight inches from the tip of the olecranon with the arm at the side.

The amputation stump assumes new physiological duties, and these vary with the type of artificial limb. The author goes into great detail in considering this new physiology.

The following points are brought out in discussing the operative technique:

1. Skin flaps should be cut so that they meet over the center of the stump without "dog ears". There should be no redundancy in these flaps.
2. The deep fascia should be maintained with the skin flap to ensure proper nerve supply and lymphatic drainage.
3. The bone and periosteum should be cut at the same level.
4. The nerves should not be intoxicated with alcohol.
5. Careful hemostasis should be accomplished. However, the author states that "drainage, even then, can rarely be dispensed with". If there is sepsis when the drain is removed in forty-eight hours, the skin flaps are separated and laid back.

Consideration is given to the guillotine amputation and the reamputation, where indicated. All such secondary amputations should be done through a clean field. The causes and the treatment of various affections are mentioned in some detail.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

PENICILLIN TREATMENT OF ACUTE HAEMATOGENOUS OSTEOMYELITIS. I.-W. J. McAdam. *The British Journal of Surgery*, **33**: 167–172, 1945.

The criteria of success in the use of any drug in acute osteomyelitis are the control of the septicaemia or pyaemia and the control of the local infection, with the limiting of bone necrosis. A study of forty cases treated with penicillin indicates that this drug answers these criteria. There was but one death in the series, despite the fact that nineteen of these patients had staphylococcal septicaemia, nine had metastatic lesions, and ten had septic arthritis.

In twenty-nine cases the penicillin was administered intramuscularly, but in eleven cases the intra-

medullar route was employed, with a sternal-puncture needle inserted into the metaphysis of the involved bone. This latter method provides a high local concentration of the drug, as well as a satisfactory blood level.

The operative treatment of this group was very conservative. Of thirty-two with infection of the long bones, only five had operative treatment. Four of these operations were performed early in the series, before the full value of conservative treatment was appreciated; and the surgery in the fifth case was only incision and drainage of a soft-part abscess.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Sarcoma of the Metatarsal Bones. A Brief Review of the Literature, with One Personal Case. Ivor J. Thomas. *The British Journal of Surgery*, **33**: 191–194, 1945.

A case of chondrosarcoma of the first metatarsal bone is presented. This tumor was said to have appeared ten months after an injury to the foot. Treatment was by amputation at the site of election. The patient was well fourteen months after the operation.

A review of the literature shows a small number of tumors of this type in the metatarsal bones. The reported rate of cure is about thirty-three per cent.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Metastatic Osteomyelitis Secondary to Tropical Ulcer. Margaret M. Shepherd. *The British Journal of Surgery*, **33**: 352–357, 1946.

In eleven patients of a group of ninety-eight suffering from tropical sloughing phagedaena, ulcus tropicum, or Naga sore, metastatic lesions developed in the long bones remote from the ulcer. The cortex of the diaphysis was involved, and all lesions healed spontaneously.

A slight amount of pain and tenderness usually called attention to the lesion, and roentgenograms verified it. Usually the tropical ulcer had been present for two or more weeks before the onset of the pain, and occasionally the ulcer was entirely healed.

Roentgenographically, the cortex showed decalcification, followed later by a deposit of new bone periosteally, but never with much absorption of bone. There was no permanent disability.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Tendon Transplantation for Radial Paralysis. R. B. Zachary. *The British Journal of Surgery*, **33**: 358–364, 1946.

In assessing the results of tendon transplantation, the chief points to be evaluated are: (1) the range and power of extension of the fingers and thumb, (2) the range and power of wrist extension, (3) the range and power of wrist flexion, and (4) the range of flexion of the fingers.

The writer has studied fifty-seven cases. In twenty-four cases, both the flexor carpi radialis and the flexor carpi ulnaris were transplanted into the extensors of the digits. Where the palmaris longus was absent, the results were bad; but when it was present, about half of the patients showed good results. In twenty-nine patients only the flexor carpi ulnaris was transplanted, and 90 per cent. of these patients had good functional results.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Fracturas del piramidal (Fractures of the Triangular Bone). M. Riosalido. *Cirugía del Aparato Locomotor*, **2**: 322–331, 1945.

Fractures of the triangular bone are rare. The author collected thirty cases from the literature and adds six cases, personally observed. The condition is commonly associated with other carpal injuries. It is a fracture of compression, usually caused by a fall upon the palm of the hand. Diagnosis is not easy and depends upon the roentgenographic findings. Treatment consists of immobilization—effective, but not too rigorous—with a palmar splint, for from twenty to twenty-five days, followed by physiotherapy and exercise.

In one case there was a temporary disturbance of the ulnar nerve. In another case pain persisted, so that a support for the wrist was required for work. Normal recovery occurred in the others.—*John G. Kuhns, M.D., Boston, Massachusetts.*

Principios terapéuticos en las artritis traumáticas (Therapeutic Principles in Traumatic Arthritis). Pablo Mendizábal. *Cirugía y Cirujanos*, **13**: 157–178, 1945.

This is a long, detailed article on the subject of traumatic arthritis. The anatomical and clinical conceptions of joints, as understood by the author, are given in some detail. The gross and microscopic pathology is given and the various tissues are described. The abnormal physiology of joint changes and of synovial function is explained. The intimate relation between the bone structure and circulation, especially with regard to the small blood vessels, veins, and lymphatics, is stressed, and the importance of small alterations is pointed out. Numerous joints and the various types of traumatic involvement are discussed. The author stresses the importance to joint function of the patient's general health and constitutional factors. Various mechanisms of trauma are given, and eighteen types of injuries to the joint are enumerated. These vary from severe external violence to minor repeated injuries.

The various types of therapy used in arthritis are discussed. A complete diagnosis with extensive

laboratory work is important, because the Wassermann and Kahn tests, the sedimentation rate, uric-acid determination, and blood count are all of importance. The author feels that metallic substances placed near joints in the treatment of fractures produce joint irritation and traumatic arthritis. This is a consideration in treatment. The indications for operations in traumatic arthritis are given, and the types of surgery include periarticular surgery on the capsule, ligaments, muscles, and tendons, and intra-articular surgery on the joint itself. The correction of bone alignment is indicated if a fracture near a joint is angulated. Among the types of surgery indicated are synovectomy, capsulotomy, tenotomy, osteotomy, arthrotomy, arthrodesis, arthroplasty, sympathectomy, and ganglionectomy. The general management includes treatment of focal infection, general systemic measures, immobilization of the joint, the use of heat, and the use of ultra-violet light.—*Louis W. Breck, M.D., El Paso, Texas.*

MALUNITED FRACTURES AND DISLOCATIONS. T. H. Somervill. *The Indian Journal of Surgery*, **7**: 85–95, 1945.

Although the textbooks usually describe the treatment for recent fractures, the fractures encountered in India, particularly in the country districts, are not presented for treatment immediately, but frequently have been treated by quacks or neglected entirely. Somervill presents an admirable study of malunited fractures and the methods of preventing malunion, based on experience gained during twenty-two years in a surgical center in southern India. He attaches importance to exercise and movement of all parts of the body, except those which must be immobilized; to a diet containing extra calcium and ample quantities of vitamins C and D; and to the administration of aluminum acetate for several months after the injury.

RECURRENT DISLOCATIONS OF THE SHOULDER JOINT. N. S. Narasimhan. *The Indian Journal of Surgery*, **7**: 123–133, 1945.

Narasimhan presents an admirable study of recurrent dislocation of the shoulder, based on a series of ninety-nine cases treated at the Madras General Hospital from 1938 to 1945. He reviews the theories of its causation, particularly those of Bankart and Codman, noting the frequency of its occurrence in epileptics and during the chronic spasms of tetanus. He believes that the treatment should be operative, describes seven types of operation, and reports a series of twelve cases operated upon, describing the pathology in each and the technical difficulties experienced with Bankart's procedure. He discusses the comparative merits of various operations, concluding that Bankart's, in which the capsule and the cartilage are sutured to the anterior rim of the glenoid, gives the best results.—*Robert M. Green, M.D., Boston, Massachusetts.*

LOS PIES ZAMBOS DOLOROSOS POSTRAUMÁTICOS EN LAS FRACTURAS DEL CUELLO DEL PIE. SUS VARIEDADES Y SU TRATAMIENTO (POST-TRAUMATIC PAINFUL VARUS FEET FOLLOWING FRACTURES OF THE ANKLE. TYPES AND TREATMENT). A. Velasco Zimbron. *La Prensa Médica Mexicana*, **10**: 27–28, 1945.

The many types of soft-tissue lesions and fractures which may be found in the ankle are enumerated. Non-union and malunion of fractures are the most important causes of persistent pain. The different types of fractures of the tibia and fibula at the ankle are all mentioned, and the reader is referred to Cotton's classification of Pott's fractures. Persistent pain following ankle fractures is usually due to a disorganization of the ankle joint, which the author calls a disharmonious relationship between the talus and the tibia.

In the treatment of the painful extremity, the simpler surgical procedures are of little value. The author recommends an arthrodesis of the ankle, and he describes his favorite type, which is a central bone graft. The joint is exposed laterally, and osteotomy is performed on the lower end of the fibula. The articular cartilage is removed from all joint surfaces. A bone graft, one centimeter by ten centimeters in size, is taken from a higher portion of the tibia and is placed across the ankle joint by inserting it into drill holes in the tibia and the talus. Details of the operation, the closure, and the postoperative immobilization are given. The author has treated ten cases, with solid fusion in all of them.

The article is well illustrated.—*Louis W. Breck, M.D., El Paso, Texas.*

L'EXAMEN RADIOGRAPHIQUE DU PIED BOT (ROENTGENOGRAPHIC EXAMINATION OF CLUB-FOOT). Pierre Marique. *La Presse Médicale*, **53**: 633–634, 1945.

The author maintains that congenital club-foot represents a true subluxation of the foot on the leg. This can be demonstrated by roentgenograms taken by the following technique: With the child flat on the back, the leg is externally rotated so that the bimalleolar axis is perpendicular to the plate. No effort is made with respect to the fore part of the foot. The central beam is centered over the bimalleolar axis, and exposures are made with the foot in complete flexion and extension. Attention is called to the fact that, in dorsal flexion, the degree of supination is markedly reduced.

On such bimalleolar profile views, the axis of the tibia normally passes through the posterior end of the talus when the foot is in extension. In flexion, the talus is displaced still farther posteriorly. In the club foot, the axis of the tibia lies well behind the talus when the foot is in extension.

For purposes of comparison and in order to determine the presence of irreducible equinus of the talus, the author recommends that the roentgenograms be made with the foot in flexion.—*Henry Milch, M.D., New York, N. Y.*

Le bilan humoral des osteopathies de famine (Fluid Balance in Hunger Osteopathies). L. de Gennes et G.-H. Deltour. *La Presse Médicale,* **53**: 678–679, 1945.

In a study of twelve cases of hunger osteopathy, the authors noted the loss of calcium, phosphorus, vitamin C, and vitamin D, and a qualitative and quantitative lack of lipoids and proteins. Although the calcium in the blood was relatively constant, there was a marked excretion of calcium in the urine.

In five cases the blood phosphatase was normal, but in one there was a mild increase and in five a marked increase in the phosphatase.

In five cases there was an increase in blood potassium with a disturbance in the calcium-potassium ratio.

In a certain number of cases, "opaque images of variable form", giving the impression of calcification of different organs, were found. The authors have termed these shadows "cutaneous creases", although they seem to arise from deposition of calcium in the subcutaneous tissues. They are never found in other emaciating conditions.—*Henry Milch, M.D., New York, N. Y.*

Ostéosarcome et maladie de Paget (Osteosarcoma and Paget's Disease). F. Layani et Cl. Olivier. *La Presse Médicale,* **54**: 145–146, 1946.

The authors report the case of a woman, aged eighty, in whom sarcoma developed as a result of Paget's disease. During the course of the disease, roentgenotherapy controlled the pain. Amputation was performed in the lower third of the femur, but pulmonary involvement was the cause of death after six months.

The case is unusual because of the age at which the sarcoma developed. The oldest previous patient, reported by Gvistel and Yanker, was seventy-eight years of age. Usually the average age at onset of Paget's disease is about forty-six, and the age of sarcomatous degeneration is about fifty-eight.

Although it is difficult to state with assurance, about 8 per cent. of patients with Paget's disease present signs of sarcoma. Pathological fracture, not common in association with primary sarcoma, is the first sign of sarcomatous degeneration in about one-third of the cases. In all, the roentgenographic findings are distinctive.

The sarcoma arises almost exclusively in bone showing the characteristic pagetoid appearance. Thus it is common to find the picture of Paget's disease with presarcomatous degeneration and with true tumor formation in the same area. In those instances where the sarcoma is metastatic, only the one histological picture is present. Because of this, the authors are of the opinion that the multiple localization of sarcomata in Paget's disease is evidence of polyosseous sarcomatous degeneration, rather than of degeneration with metastatic spread of the tumor. In most instances, the prognosis is bad. The extreme life expectancy after discovery of the sarcoma is about two and one-half years, with an average expectancy of one year.—*Henry Milch, M.D., New York, N. Y.*

La problème de l'ostéochondrite dissequante (The Problem of Osteochondritis Dissecans). J. A. Mathez. *La Presse Médicale,* **54**: 211–212, 1946.

The author undertakes to support the thesis that osteochondritis dissecans is traumatic in origin. He shows that the process occurs at the most prominent part of the curvature of the condyle. It always begins in the bone, and the cartilage covering it may remain intact for a considerable length of time. The bony surface is always convex. This outline is mathematically determined by the contour of the condyles, and is not related to interference with blood supply. In the opinion of the author, osteochondritis dissecans is to be looked upon as a fracture, caused by vibration.—*Henry Milch, M.D., New York, N. Y.*

Luxo-fractura de la articulación de Lisfranc (Fracture-Dislocation at Lisfranc's Joint). Augusto Wybert y Juan Alberto Pérez Rovira. *Revista de la Asociacion Medica Argentina,* **59**: 481, 1945.

The authors report the case of a twenty-year-old male, whose foot was crushed and who was hospitalized about two weeks after injury. Examination disclosed a swelling on the dorsum of the foot, in the region of the tarsometatarsal joint. The longitudinal arch was depressed, the outer border of the foot was concave and shorter than on the opposite side, and there was definitely localized tenderness. The roentgenogram disclosed a fracture of the internal cuneiform of the base of the second metatarsal, with a lateral dislocation of the fore part of the foot. Manipulation under anaesthesia and traction with wires through the calcaneus and through the metatarsal heads was unsuccessful. Reduction was accomplished after open operation, levering the fractured second metatarsal into place.

The authors point out the important role of the second metatarsal head. Although it was originally believed impossible for dislocation to occur without fracture of this bone, this has since been found to be untrue.—*Henry Milch, M.D., New York, N. Y.*

ARTRODESIS DEL HOMBRO EN LA PARÁLISIS INFANTIL. TÉCNICA PERSONAL (ARTHRODESIS OF THE SHOULDER IN INFANTILE PARALYSIS). Valentín C. Girardi. *Revista de la Asociacion Medica Argentina,* **59**: 485, 1945.

Scapulohumeral arthrodesis, first devised by Albert in 1879, was popularized by Vulpius in 1898. In general, the extra-articular type of operation is reserved for the tuberculous osteo-arthritis, while the intra-articular operation and the combined operation are employed for the paralytic cases. The fusion operation is to be preferred to muscle-transplant or nerve-grafting operations. Fusion in children may be performed as early as the sixth to ninth years, but the optimum age is between ten and twelve years. Following the recommendations of The American Orthopaedic Association Committee, the author advises fusion in right-angled abduction with the arm in 35 degrees of flexion and 25 degrees of internal rotation.

The many different types of fusion operation which have been recommended are briefly reviewed. The author describes his own technique. The skin incision is made from the region of the acromial tip down to the apex of the axilla. The subcutaneous tissues are sectioned in the same plane. The cephalic vein is tied and cut, if necessary. The deltoid muscle is then opened by a T-shaped incision, the long arm of the T descending along the axis of the humerus. The humerus is exposed and an osteoperiosteal graft, six centimeters by one centimeter, is prepared. The head and the glenoid are then denuded of cartilage. The head is placed in the ideal position and fixed, by means of a Lambotte screw, into the glenoid. The bone graft is then fixed along the anterior aspect of the glenohumeral joint, and the wound is closed.

Immobilization is carried out by means of a previously prepared plaster spica. This is retained for a period of from three to six months, or until the roentgenograms disclose firm bony union.—*Henry Milch, M.D., New York, N. Y.*

EL TRATAMIENTO DEL DOLOR EN LA ARTROSIS DEFORMANTE DE CADERA, POR LA NEUROTOMÍA DEL OBTURADOR (OPERACIÓN DE SELIG) (TREATMENT OF PAIN IN DEFORMING ARTHRITIS OF THE HIP BY OBTURATOR NEUROTOMY: SELIG'S OPERATION). Guillermo F. Cottini. *Revista de la Asociacion Medica Argentina,* **59**: 884–891, 1945.

The therapy of coxarthritis is primarily the treatment of pain. The limitation of motion is of secondary consequence. Many different types of treatment have been recommended, but the neurotomy suggested by Selig seems to have special value, particularly in patients over sixty, in whom other procedures are contra-indicated.

The operation is based upon the fact that the hip joint is supplied by sensory nerves from the sciatic, the femoral, and the obturator nerves. In many instances simple section of the obturator nerve suffices; in other cases, additional section of the sciatic or the femoral branches, as well as drilling operations, may be necessary to bring about results.

The operation is extremely simple and has no contra-indications. The author performs it under spinal anaesthesia and prefers to divide the obturator nerve on the pelvic side. The approach is made through an incision splitting the rectus muscle, and has been performed in eighteen cases.

In eleven of these cases, follow-up results have been obtained. Of these, five were excellent, two were good, and four were unsuccessful. In these four cases, only the obturator nerve was divided.

The author believes that the procedure exerts its best effects in patients who have contracture of the adductors. It would appear, therefore, that part of the effect is of anaesthetic origin and part is due to conversion of the adduction contracture.—*Henry Milch, M.D., New York, N. Y.*

CONDRO-OSTEOMAS MÚLTIPLES: EXOSTOSIS METAFISIALES—EXOCONDROSIS OSTEOGÉNICA (MULTIPLE OSTEOCHONDROMATA). Conrado Zuckermann. *Revista Mexicana de Cirugía, Ginecología y Cáncer,* **13**: 169–186, 1945.

This is a case study of a nineteen-year-old boy with multiple osteochondromata involving the lower tibia, lower femur, upper tibia, and upper fibula. The tumor just below the knee was first noticed after a minor injury; it was excised and the pathological sections carefully studied. A review of the pathological findings revealed fibrous connective tissue, cartilaginous tissue, and bony tissue.

The author gives an excellent review of the subject of multiple osteochondromata. These tumors invariably originate at the cartilage plate at the end of the long bone, in the metaphysis. They rarely become transformed into blastomata. They occur more frequently in males than in females, and there is a definite hereditary tendency. They are frequently multiple and sometimes symmetrical. The author states that occasionally these tumors are noted in the flat bones, also. A bursa sometimes forms over the tumor. The differential diagnosis is not too difficult, and roentgenograms of many of the long bones should be taken to ascertain whether or not the tumors are multiple. No treatment is known for these tumors except excision, and this should be done if the location, size, or pressure symptoms warrant it.

This article is an excellent review of the subject of osteochondromata. It is well illustrated with reproductions of roentgenograms and microscopic slides.—*Louis W. Breck, M.D., El Paso, Texas.*

LES MALFORMATIONS DE LA ROTULE DANS LA GENÈSE DE LA LUXATION HABITUELLE OU CONGÉNITALE DE LA ROTULE (MALFORMATION OF THE PATELLA IN THE ETIOLOGY OF HABITUAL OR CONGENITAL LUXATION OF THE PATELLA). P. Swynghedauw et E. Laine. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur*, **31**: 25–35, 1945.

Attention is called by the authors to a congenital deformity of the patella which can easily be diagnosed on axial x-rays of the patella. There is then a widening of the patella in the anteroposterior plane, and also a change in the medial portion of the patella, which becomes shorter and more globular.

In the absence of this roentgenographic finding, the treatment of habitual dislocation requires the usual capsular procedures or the transplantation of the tibial tubercle. In the presence of a congenital deformity of the patella, however, the authors consider a patellectomy as the treatment of choice.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

INTERVERTEBRAL DISC LESIONS. GENERAL DISCUSSION AND CONSIDERATION OF TREATMENT IN MILITARY SERVICE. Exum Walker. *Southern Medical Journal*, **38**: 832–834, 1945.

Sciatic radiation due to root pain, associated with paraesthesia, is the chief diagnostic symptom in lesions of the intervertebral disc. This pain can be produced by direct stimulation. The sensation of the foot "going to sleep" could result from ischaemia of a section of the nerve root, and consequently a physiological neural block. Besides the operation upon the disc, additional relief is obtained in certain cases by section of the sensory portion of the nerve root involved. Some surgeons advocate fusion of the vertebrae, but this does not always give relief, and prolongs the operation and the convalescence. Conservative treatment should be used in the majority of cases.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

TREATMENT OF PERIPHERAL NERVE INJURIES. Arthur M. Pruce. *Southern Medical Journal*, **39**: 289–291, 1946.

Two new diagnostic procedures in peripheral-nerve injuries have been introduced: the neurodermometer (Richter) and a device for the determination of galvanic tetanus (Pollock). The former is an objective method for determining the area of anaesthesia, independent of the patient's cooperation. With the use of the latter, evidence of muscle re-innervation is shown much earlier than by standard methods. Both of these techniques are as yet in the formative stage.

The paraffin bath is very useful. Whirlpool baths are followed by ultraviolet radiation to improve the circulation and the condition of the skin. Exercises and galvanic stimulation are used. This report is from the service at Lawson General Hospital, Atlanta.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

SPINAL FUSION FOLLOWING REMOVAL OF INTERVERTEBRAL DISK. Edward L. Compere. *Southern Medical Journal*, **39**: 301–306, 1946.

Spinal fusion alone has relieved many patients with low-back pain, but some continue to have sciatic pain after this operation. Many patients have been relieved of their pain by removal of the intervertebral disc, without fusion of the spine. Some are not relieved by this operation, or later have a return of their pain. The anatomy and function of the intervertebral disc are discussed. In both animals and humans, after removal of the disc, arthritic changes tend to develop, both in the articular facets and along the margins of the vertebrae. During the past five years the author has combined removal of the ruptured disc with fusion of the laminae by the Hibbs technique. He uses many chips and splinter grafts to get a solid fusion of the vertebra above and the one below the involved disc.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

TOWEL CLIP FIXATION OF FRESH CLAVICULAR FRACTURES. Milton C. Cobey. *Southern Medical Journal*, **39**: 307–311, 1946.

The method of reduction and fixation of the clavicle with towel clips was in use at Johns Hopkins Hospital in 1934. The patient is given a general anaesthetic and placed on a fracture table with a single support under the shoulders. The area of the clavicle is prepared for surgery. Small stab wounds are made. Carefully the points of the clips are inserted into the bone on each side of the fracture, about one inch from the fracture line. The handles should overlap after reduction, if possible. The fluoroscope may be used, but is not essential. Small colloidin dressings are applied, and the handles are tied together. Plaster-of-Paris may be molded about the handles for fixation. A jacket type of plaster cast is applied, without a spica. The handles are not fixed to the plaster cast. Patient may be ambulatory.

This method has been used over a period of eleven years. No complications have occurred. It has been used in only 14 per cent. of cases, and then only after conservative methods have been tried. The author is opposed to open operations on the clavicle.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

THE MOLDED BONE GRAFT. Arthur J. Barsky. *Surgery*, **18**: 755–763, 1945.

Barsky advocates the use of molded bone grafts in selected cases. The method, which he has used in fifteen cases, is carried out as follows:

The loss of contour is studied carefully, and roentgenograms are taken. A plaster study model is

prepared, which should include the normal side as well as the area of defect. With wax, the area of defect is built up on the plaster cast. The mold or splint is made of sheet lead, one thirty-second of an inch thick, and it is pressed into shape over the restoration and onto the normal tissue beyond.

The recipient area is prepared first, and then thin shavings of dense bone and large quantities of cancellous bone are taken from the crest of the ilium. The cancellous bone is cut into pieces a few millimeters in size and is deposited in the cavity. Over this are placed the thin shavings of bone, immediately beneath the surface of the skin. After closure has been completed, the molded splint is applied, with a thin layer of dental modeling compound between it and the skin. A pressure bandage is then applied.

The mold is left in place for four or five days, but may be removed temporarily in order to remove sutures.

This type of graft is advocated only as a contour restoration for defects in the skull and bones of the face, and is not recommended for bones which bear weight or are subjected to functional stress.

Fissures of the Articular Cartilage of the Patella. Occurrence in Multipartite Patella. Charles J. Sutro. *Surgery*, **19**: 251–266, 1946.

Degenerative lesions of hyaline cartilage occur on the patella in much the same way that they do upon other articular surfaces. Their presence may be characterized by areas that are soft and spongy, which have been described as chondromalacia patellae, or by cracks and fissures in the articular cartilage. Trauma, especially a direct blow which drives the patella against the articular surface of the femur, is probably the primary etiological factor. Repeated minimum traumata produced in ordinary daily activity must play some role, however. The symptoms accompanying fissures of the articular cartilage are often acute, and occur shortly after a specific injury or after unusual physical exertion. The patient may complain of sharp pains, instability, temporary locking, enlargement of the knee region, and inability to bear weight. Later the symptoms may be described as "locking"; loud crepitations are also a complaint. When the examining physician moves the patella back and forth or up and down against the articular surface of the femur, the patient may complain of severe pain; crepitation is often felt.

The author has reported fifty-eight cases. The patients with relatively mild symptoms were treated with the usual conservative measures of protection, heat, and massage; they were advised to avoid all exercises, including marching, walking, and dancing, in so far as possible, for three or four months after the injury. When the symptoms persisted in spite of conservative treatment, surgery was advised. In nine of the eleven cases operated upon by Sutro, only the injured portion of the cartilage was removed. In only one case was the entire patella excised.—*Edward L. Compere, M.D., Chicago, Illinois.*

The Use of Drainage in Operations on the Spine. Leo S. Lucas and Joseph H. Gill. *The Western Journal of Surgery, Obstetrics and Gynecology*, **53**: 379–380, 1945.

It is usually recognized that the chief complication of operations on the spine is hematoma formation, inasmuch as they may lead to secondary infection by retrograde and hematogenous routes, or to chronic sinus formation and osteomyelitis of the spine. To avoid this complication, the author inserts one small cigarette drain in the floor of the wound before the wound is closed tightly. This is left in for exactly twenty-four hours. In a series of 104 cases in which this method was used, there was no case of hematoma, chronic sinus formation, or infection of the deep structures.—*F. Harold Downing, M.D., Fresno, California.*

Chronic Sclerosing Osteitis. Henry W. Meyerding. *The Western Journal of Surgery, Obstetrics and Gynecology*, **53**: 413–421, 1945.

In a period of thirty-two years—from 1912 to 1945, inclusive—eighty patients with chronic sclerosing osteitis have been seen at the Mayo Clinic. This represents a 2 per cent. incidence in 4,000 cases of osteomyelitis. The outstanding symptom is persistent pain of varying severity, which may be present for months or years and usually becomes worse at night. It is deep-seated, and is usually located in the shafts of the long bones. The roentgenographic findings are significant. They show a localized area of dense sclerotic bone with a region of lesser density, often round or oval. There is considerable proliferation of the cortical bone, with swelling of the cortex, which is sometimes mistaken for malignant osteogenic sarcoma or syphilitic periostitis. The regions may partially involve the entire cortex for a distance of several inches, or they may partially or completely close the medullary cavity and produce a dense, spindle-shaped mass in the shafts of the long bones.

The treatment is surgical, and the extent of the operation depends upon the degree of involvement. An attempt has been made to saucerize the involved area. Multiple drilling did not prove satisfactory. The wound is sprinkled with sulfathiazole and closed without drainage in the majority of cases. If external support is required, plaster casts are used. Of fifty patients traced from two to thirty-one years, thirty-four (68 per cent.) obtained complete relief from symptoms; seven (14 per cent.) obtained partial relief, and nine (18 per cent.) had had no improvement.—*F. Harold Downing, M.D., Fresno, California.*

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